Optoelectronics in Hamamatsu
In search of a photon valley

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I. Introduction

This paper presents the case study of the emergence of optoelectronics in Hamamatsu. Hamamatsu is a manufacturing intensive region striving to survive in the ever tighter global competition, with imminent signs of industrial hollowing. The region has seen several waves of industrial transformations, first in textile and related equipment, second in musical instruments and automobile. As their manufacturing base faces increasingly tough pressures for reducing costs, and as more companies plans to move their production offshore, the region has been on a lookout for the next potential industry. Hamamatsu has one globally renowned company called Hamamatsu Photonics (HPK) which fits the image of the 21st century manufacturing. It is high tech, highly profitable and high value adding, and has remained competitive throughout the 1990s. This is how optoelectronics came to represent the ray of hope for the region.

The question is whether optoelectronics has become a significant industry to lead the future of the region? What conditions can enhance its success? In order to examine these issues, the paper addresses the following specific questions. First, what does the optoelectronics sector in Hamamatsu look like, and what level of success does it exhibit for the region? Second, what has been the nature of technological developments to date? Third, what role, if any, has the region played in its development? Fourth, what role if any have the universities and public institutions played in their innovation processes? Fifth, what could have enhanced their roles? Finally, what are the lessons for Hamamatsu and other regions?

The paper shows that optoelectronics in Hamamatsu is a small cluster of companies, with at least one globally competitive albeit mid-size company, a small number of spinouts from HPK, and others diversifying from other products. While HPK has grown to become a globally competitive company, there has been little evidence of dynamic growth of the sector in the region. The spinouts from HPK occurred only as exceptions. Companies that have diversified into optoelectronics have done so mainly in response to changing user needs, often arising outside of the region. Indeed, there have traditionally been little supply relationships among optoelectronics companies in the region, partly owing to the fact that HPK as a leading company was vertically integrated with little need for supply chains.

More recently, there have been increasing interactions among these local companies, which are forming a new kind of dynamics in the region. HPK has formed a technical collaboration with another major local machinery company leading to a new product released in 2003. HPK has also been engaged in a collaborative research project with several smaller companies in the

region. While these are promising developments, it is not clear that they are enough to ignite regional economic growth.

Why were there so little interactions before? What helped develop interactions? And why do they still fall short of forming the basis for solid regional economic growth?

This paper argues that these companies remained independent in their technological development until recently. HPK as the first optoelectronics company in the region, developed as an indirect spinout from the Electronics Institute in Shizuoka University. Only a small number of specialist companies spun out of HPK owing to its corporate practice in life employment and expectations for loyalty. Other companies have diversified into optoelectronic products, spurred mainly by the general rise of optoelectronics applications. The nature of technological development was different depending on the level of company's technological capacity as well as aspirations, for instance, locally competitive firms went through different type of technological development from nationally or internationally competitive ones.

The region provided an important industrial base for spinouts and diversification. HPK was critically dependent on the local university engineering research group in its early days. Several specialist optoelectronics companies spun out of HPK diversifying Hamamatsu's production, but with little interaction among them until recently. The region provided essential infrastructure for these companies to expand locally, by providing roads, other transport infrastructure as well as factory spaces.

The local universities played different roles to different types of companies, depending on the level of their technical capacity and aspirations. At the minimum, graduates and their social networks provided a visible underpinning to the local business community. These sometimes led to commercial relationships, but by and large alumni relationships remained at the social level, and companies remained technologically isolated from each other.

There were a few instances when the local universities played a greater and more visible role: HPK emerged out of tight collaboration with Shizuoka University; and HPK developed deep relationships with the local medical university when it was delving into medical applications for the first time. However, such deep relationships appear to be an exception rather than a norm. Although HPK maintains research and training contacts with these local universities on a routine basis today, most of its cutting edge contacts lie outside of the region, with a number of national and international universities. It looks as though HPK outgrew the local scientific capacity, or that the local universities did not co-evolve in their capacity to keep pace with HPK's scientific development. Shizuoka University ceased to foster new spinouts or to forge deep ties with other companies, as it became more academically oriented, and less interested in working with industry.

Emerging interactions in the recent past provide a significant departure from the past. Local firms are for the first time experiencing shared technological development through collaborative diversification. These developments resulted from government sponsored collaborative research, which mandated collaborations among local firms. Academics played a

critical coordinating role in these collaborative research projects. However, the government cannot be expected to keep on feeding large subsidies to foster such interactions, and local academics are not yet well developed to play the coordinating role. Although there is today a critical mass of HPK spinouts with emerging interaction among them, this is unlikely to be sufficient for continuing the shared path of technological development.

The story of Hamamatsu is one of a region that has done everything it could to push the regional capacity for industrial development. The region made a concerted effort in developing essential infrastructure for industrial development by building roads, railways and industrial estates. The region attempted to develop a Technopolis, a city for technologically oriented companies and intellectual hubs with Shizuoka University and the Industrial Technology Center. Realizing that co-location was not enough to foster interaction among the key players, the region actively sought collaborative research projects among multiple firms and universities. The main shortcomings appear to be two-fold: the gradual isolation of Shizuoka University from industry with its academics unable to play adequate roles as technological coordinators; and central government superstructures that distracted local players from the content of the initiatives.

One important lesson for other regions is that it is unlikely for a single university to meet all the local needs, given diverse needs of companies. More specifically, every university will have a certain technological standard, by the virtue of its quality of faculty and students. If it is high, it could meet the cutting edge scientific needs of internationally competitive companies. If it is low, it could meet the upgrading needs of local companies. The critical question then is what level to target the technological standard of local university to.

The paper is structured as follows. The first section describes research methods and key data used in the study. Second, the economic and institutional context of Hamamatsu is described. Third, an overview of optoelectronics industry in Hamamatsu is given.

The fourth section illustrates the nature of technological developments in HPK showing how their approach to technological innovations evolved as their products moved from imitation to becoming national leaders, and ultimately international leaders on the one hand, and as their internal technical capacity developed from low to high on the other. The section ends with a short summary of the role of regional factors and universities and public research institutions in HPK's innovation history.

Fifth, the technological developments in other optoelectronic companies are described to illuminate the nature of dynamics going on in these companies. Specifically four types of optoelectronics companies are discussed: (a) a mid-size Specialist Company; (b) a mid-sized non-specialized company with intention to grow further in optoelectronics; (c) small start-up optoelectronics companies; (d) small scale non-specialized subcontracting companies. A fifth category, a university startup, is also presented, albeit outside of optoelectronics. The main purpose is to understand the nature of relationships between a start-up company and Shizuoka University. At the end of the section, the role of the region and universities and public universities will be summarized briefly.

The sixth section explores more fully the role of universities and public institutions in such technological developments, if any. The roles of Shizuoka University and Hamamatsu Medical University in particular are discussed, historically and at present. The paper closes by discussing the potentials and challenges faced by Hamamatsu in terms of further developments in optoelectronics, and lessons learned for other regions.

II. Methods and data sources

The case study is based on 40 interviews with 37 key informants; with 9 people representing the government (national (3), prefecture (2) and city (4)); 10 people from three universities and the prefecture's Industrial Technology Center; and 21 persons from 11 companies. The interviewees were identified in a cascading manner through interviews starting with key personnel at the Ministry of Economy, Trade and Industry, the chamber of commerce in Hamamatsu, as well as the Regional Collaboration Center of the University of Shizuoka.

Company selection. Hamamatsu Photonics (HPK) is known internationally as a successful optoelectronics company, producing specialized optical sensor equipment and parts. There are only two exclusively optoelectronics companies that are listed in Tokyo Stock Exchange; they are both mid-size, HPK with employment of about 2000 and another, Company A, with nearly 400 employees. The other companies were selected from the list of companies from the most recent survey and interviews, to ensure all key categories are covered. Company B represents a category of mid-sized companies that are moving into optoelectronics from other product areas. Two start-up companies were selected as specialist start ups in optoelectronics. Two subcontractors related to HPK were included to examine supply relationships in the region, and represent small companies surviving based on subcontracting, who are getting increasingly involved in optoelectronics, by the virtue of their clients' interest. One recent start-up company was included in the interviews as the only recent case of university start-up. Several other supplementary references were also used, such as local technological magazines and books that introduce upcoming mid-tier companies in the region, to check that the company selection was reasonable.

For HPK, the detailed corporate history which documented in considerable detail many significant technological events was used extensively for events up to the early 1990s. Materials on institutional websites whenever available were also used to obtain better contextual understanding of the organizations.

For company interviews, emphasis was given to identifying key technological breakthroughs, and key inputs and processes that enabled them. About 40 such sub-cases of technological innovation were subsequently examined in terms of key inputs and processes. Similar business breakthrough events were examined from the other companies, again to explore the key inputs and processes. Most interviews lasted 2 hours or more, with 5 shorter (half an hour) interviews with HPK staff.

III. Contexts of Hamamatsu

III-1. Economic contexts

Geographical context. Hamamatsu is a mid-size city with a population of 590,000. The industrial base, however, spans a wider region covering 2 neighboring cities of Hamakita and Tenryu as well as 2 townships, Hosoe and Insa, with a total population of 710,000. It is located in the middle of Japan's largest and main island, Honshu, in between Tokyo and Osaka, both just 2 hours away on the bullet train, and close to Nagoya, which also provides the closest airport for Hamamatsu. It is well placed in terms of transport infrastructure as a major highway that links Tokyo and Nagoya passes nearby.

Industrial structure. Hamamatsu is a city well known for its vibrant manufacturing which comprises 30% of its employment as shown in Table 1. As a proportion of total employment, manufacturing has been declining since its peak of 40% in 1970, though the overall level of employment has been fairly stable at between 90,000 and 100,000 since 1970.

Textile, musical instrument and automobile textile have been the three leading manufacturing sectors whose influence peaked in successive waves. Textile has been declining in the last thirty years, from its peak in the number of businesses in 1970, in employment and production in the 1980 (Table 1 and 2 and Fig 1). Musical instrument as a sub-sector represented by two competing companies, Yamaha and Kawai, has passed its prime in the 1990s, with strong competition from other Asian countries such as Korea. Its sales volume remained roughly the same for over a decade.
Automobile industry, on the other hand, has been providing a stable base throughout the 1990s, with a resilient growth both in employment and production in spite of the fear that the industry may be losing its competitiveness because of the high cost of labor. With leading companies such as Suzuki and Yamaha, even after Honda moved its headquarters out of Hamamatsu, automobile industry has been an important source of employment. Indeed, Hamamatsu's manufacturing appears to have survived against competition from neighboring countries with cheaper labor costs, by bringing in cheap foreign labor into the city: the number of registered foreigners grew explosively from 3600 to 19000 between 1990 and 2000.

Today, the idea of industrial hollowing that haunted the region for the past decade is quickly becoming a reality. In 2001, Yamaha announced a relocation of its 50cc scooter production to Taiwan, and Kawai also decided to move its electronic piano production to Indonesia. While Suzuki publicly announced that it will not relocate its factories to other Asian countries to assure the public, they also admit that the volume of its sub-contracting work within the region will necessarily diminish.

It is in this regional context that optoelectronics, which largely falls within the electrical equipment sub-sector, came to be regarded as the new and emerging industry of the future, even though people know little beyond the single success of Hamamatsu Photonics (HPK). The company has little supply chains within the region and is very different from other leading companies in that it provides much smaller employment and in that it specializes its small batch customized production.

Cultural traits. Hamamatsu's "entrepreneurial culture" and ability to produce competitive companies has been noted and reported by several business writers, as early as in 1980 (Kajiwara 1980), and as recently as 2001. The more recent book describes Hamamatsu as an unusual region with ability to foster new and vibrant companies (Takeuchi 2002). Hamamatsu is also considered as one of more successful cases of the Technopolis Initiative of the 1980s, a central government initiative to build high technology regions implemented by local governments, with Hamamatsu being the better performer among 20 such initiatives nationwide (Sakamoto; Harada 2001), though the locals appear to see it as a half baked initiative that did not meet its promise.

Today, the way the locals explain the entrepreneurial culture of the place is remarkably consistent. They all talk about the legacy of the feudal period in the 17-18th century when Hamamatsu Castle served as a stepping stone for upcoming feudal lords. They came and went, developing a culture of tolerance for new comers, generating depth in craftsmanship as the region absorbed different crafts from other regions brought in by these lords. They also refer to the tradition of "Yarumaika" spirit in Hamamatsu, which means somewhere in between "can do" and "will do." Local competition is also seen as a key for forcing companies to work harder and be successful. There are several tales of famous battles between competing companies; Kawai and Yamaha, or Yamaha and Honda. These are clearly folklores that are told and retold among the locals, and may have significant impact on the local psyche of emerging entrepreneurs.

Comparative perspectives. When compared against other cities, Hamamatsu ranks 19th in terms of population, 11th in manufacturing production; 8th in the number of businesses; but low in terms of government roles – 34th in public research employees and 25th in city expenditures on industry and commerce. This fits the popularly held "image" of Hamamatsu, which is that it is an entrepreneur-led case of success, where the public sector is seen to have contributed relatively little.

In spite of a popular image of entrepreneurship, Hamamatsu does not have a higher rate of new business start up. According to Ito, who analyzed business statistics and a list of businesses from Somusho, the start up rate as defined as the number of start-up companies as a percentage of the total number of companies has been the third lowest at 1.8 among 10 metropolitan regions in 1996-1999, and in fact has been low through out the decade (Table 3)(Ito 200-). The rate of business closure has been the lowest among the 10 regions declining from 4.9 in 1992-1994 to 4.5 in 1996-1999. In contrast, Ito found that the rate of business conversion, defined as the percentage of companies that change its main business to a new field, was the highest at 1.1 percent against the 0.5 average in other regions. Ito concludes that Hamamatsu's entrepreneurship is perhaps characterized by dynamic business development and conversion rather than start-ups.

III-2. Institutional contexts

Local governments. The local governments are responsible principally for the provision of infrastructure both in terms of roads and factory sites for manufacturing activities. For

infrastructure, Hamamatsu has done reasonably well, with connectivity to Tokyo and Osaka both by the bullet train as well as highways. It has developed a number of industrial estates, including special sites such as the Technolopolis which aimed to bring together high technology companies.

Local governments also provided limited amount of funding for research and technical support services. The research support is rather small and considered insignificant by recipient companies, but the reputation that comes with such an award has been helpful for companies aspiring to develop a better image. The prefecture government also provides technical services through its Industrial Technology Center, which has been well used by small and medium size companies that cannot afford to buy their own testing equipment.

Several prefecture and city officials pointed out that what they can do for the region is extremely limited, because they have little resources that they could use on their own right. Rather, their main role is to lobby for central funds by creating a story that is in line with the central government requirements. They themselves have little money that they can dispense with.

Lobbying for central funds. One thing that the local government does with strong support of local companies and the Chamber of Commerce is to lobby for national funding. The experience of the Technopolis is a good example. Hamamatsu was one of the earliest to start lobbying for their inclusion in the national plan to establish Technopolis (Yamazaki 1998). The successful lobbying effort mounted by Hamamatsu to win national support echoes several other historical tales old and new where they put up similar lobbying campaigns to compete against other cities, such as establishment of Hamamatsu Industrial School in 1922, which later evolved into the Faculty of Engineering of Shizuoka University, or in the establishment of national university called Hamamatsu Medical University in 1974. In each case, Hamamatsu moved very quickly, mobilizing both key industrialists as well as politicians, to develop a convincing case of why Hamamatsu should be supported to the national government.

If local governments wanted to achieve anything, they had to obtain national support and funding. Lobbying for national assistance appears to be a major preoccupation of local governments, and the vast amount of preparatory effort is then dominated by the logic of procuring national funds rather than the logic of what the city needs.

Hamamatsu Technopolis is reported to be one of the more successful cases among 20 or so Technopolis initiatives (Harada 2001) owing to two distinguished accomplishments. First, they managed to fill all the plots created in the Technopolis – and indeed the very fact that this is quoted as a success criterion tells more about the failures of other Technopolis. Second, they managed to convince Shizuoka University and the Ministry of Education and Culture to establish their Regional Collaboration Research Center on the Technopolis site.

Although the latter sounds rather trivial, this was indeed a significant accomplishment in the mid 1980s. Many academics were unwilling to work with industry in these days. It took the planners of the Technopolis several years before they could line up university professors to participate in their workshops. It was also legally impossible for the national university

building to be built on a piece of land that was owned by local governments. There had to be innovative solutions to work around such a regulatory problem. With all that effort that went in, today, the center's activities cannot take place effectively because it is too far removed from the main campus, with little public transport to help local transfers. The key activities of the university did not move to the new site.

Hamamatsu Technopolis worked well as far as physical infrastructure is concerned – buildings were built, and plots were filled. It is when it comes to the interactions that were generated around the place that it is widely recognized that it has not done as much as originally hoped for. There has been little interaction among companies that are located there, and indeed there are little reasons to expect them to engage with each other simply because they occupy neighboring plots. The Technopolis Promotion Organization has been placing much greater emphasis on the development of business networks for some time – but with little results to date. Some observers feel that the lack of public research functions such as a university has been critical in their inability to penetrate through such corporate walls.

Industrial Technology Centers. The basic mission of the Industrial Technology Center has been to serve the needs of small and medium scale companies, traditionally through testing and equipment services. Its level of technological capacity has been basic, insufficient for innovative interactions. Today, it has aspirations to provide higher level technical advisory services, based on increasingly active research capacity in-house.

Hamamatsu center is located inside the Technopolis and has had an optical technology group for over a decade. They now have five staff allocated to optical technology, including a retired professor who works as an advisor. They do not appear to have established a solid reputation or a track record of assistance yet, perhaps because there are fewer companies who need their help. However, they have key equipment that valued by specialist companies, and they are also engaged in a joint research orchestrated by HPK and learning fast.

Universities. Hamamatsu has several universities: the faculty of engineering of Shizuoka University, formerly Hamamatsu Technical High School which was amalgamated into a national university structure along with other faculties mainly in Shizuoka City; Hamamatsu Medical University, which was established in the 1970s as a result of successful lobbying effort with central government support; and several more newer private universities which specialize in business and non-technical subjects.

Hamamatsu Technical High School has a glorious history, particularly of being a home to a well known engineer who pioneered in television technology, named Prof. Takayanagi, who worked there on and off between 1920s and 1940s. After the war, the School was upgraded into a faculty of engineering and became amalgamated as a part of Shizuoka University along with several other schools in Shizuoka. This was a national policy advocated by the occupation government to enhance regional university systems similar to the US. National universities thereafter were subjected to funding policies from the central government. For Shizuoka University as a mid-tier national university, it was not easy to compete against older national universities (former imperial universities such as Tokyo, Kyoto and Tohoku) for funding pioneering activities. It was therefore considered a substantial boon for the electronics

engineering group, a legacy of Takayanagi's research, to win a status and funding as a national university research institute in 1965. It was also one of the first non-imperial universities to establish a doctorate program in 1976. The faculty of engineering formed an optical electronics division in 1984, but abolished it through reorganization in 1996.

The faculty of engineering has an active and organized alumni group, which is unusual for Japanese universities. The alumni group reckons that there are about 60,000 active alumni engineers in Hamamatsu, which is a substantive number given the size of manufacturing population in Hamamatsu, which is of the order of 90-100,000.

In spite of reputation implied by its history and volume of output graduates, the faculty has until recently been perceived as inactive and unresponsive to local industry's needs. The faculty had become more academically oriented and isolated from industry as a result of becoming part of a university with its metrics on publications rather than practical applications, and the mood against close relationships with industry within the university.

Hamamatsu Medical University was established much later in 1974, by which time, the fury of student movements had subsided, with the social mood that negated demands of militant leftists. Developed as a single faculty university, it was much simpler for the university to take action as an organization, and far less prone to criticism in working with industry. Medicine as a disciplinary community also had distinctly different relationships with external communities, particularly because of its university hospital. Professors were also clinicians, and were therefore interested on technological developments, purely from practitioner's perspectives.

IV. Optoelectronics in Hamamatsu

The earliest reference to optoelectronics as an emerging industry for Hamamatsu appeared in the mid 1980s, prompted by the rising reputation of Hamamatsu Photonics (HPK). The first status report on the industry was written by the Prefecture's Commerce and Industry section in 1986 (Section 1986), spurring the region's expectation for this to become a leading industry as reflected in local magazines (anonymous 1987). Since then, there have been two other surveys undertaken on the industry in 1991 and 2002 respectively (Center 1991; Rodobu 2002). Although the three survey reports took somewhat different approaches, methods and items, which limit comparisons over time, they do provide some interesting historical insights[1].

Unfortunately the scale of optoelectronics as a sector is one area where there remains considerable fuzziness. However, the initial period of massive new entry and interest appears to have subsided, with a steadier stream of entrants. There appears to have been limited expansion and diminishing entry expectations into the sector in the recent past. The 1986 survey approached 71 companies that were "considered" to be active in optoelectronics

[1] There are two main changes. First, the sampling method changed. In the first survey, they approached 71 companies that were known to operate in optoelectronics related industry. In the second and third surveys, the questionnaires were distributed to 1000 or more companies that may be engaged in optoelectronics products. While most of the questions appear similar across the two earlier reports, the third one collapsed and changed many of the items, thereby limiting comparison.

products and received responses from 40 companies. The 1991 survey undertook a much wider survey sample of 1050 companies, received responses from 544, of which 66 companies reported as already undertaking optical technology industry, with 81 more companies expressing interest in entering the market in the future. In 2002, the sample was expanded to 1505 companies, with 308 responses, of which 61 companies were found to be already active in optoelectronics, and 16 more companies indicating future plans to do so.

The crude estimate would put total employment in optoelectronics in the range of 4000-10,000 which is anywhere in the range of 4-11% of manufacturing employment. Though this may seem significant the figures include a significant number of employees working on non-optoelectronic portion of companies with diverse products.

The national statistics provided by the Optoelectronics Technology Promotion Association showed in the mid 1980s that optoelectronics production grew from 90 billion yen in 1980 to 900 billion yen in 1985, with further predicted growth to 12 trillion yen by 2000. A more recent estimate of the production in 2000 by the same organization is 4.6 trillion yen. Even though the growth has been less than half as expected, there has been a tremendous growth with five fold increase in production in optoelectronics in Japan. In contrast, HPK's total sales grew from about 18 billion in 1985 and 50 billion yen in 2000 a threefold increase, and there have been little signs of growth in the total employment in optoelectronics in Hamamatsu. The sector does not appear to be meeting its growth promise in comparison with national records.

Table 5 shows that a majority of these companies have consistently been small and medium scale companies, entering the market recently, with only a minor share of their overall production in optoelectronics products. There are some discernible changes over time. Whereas 60% of companies had formed in the previous 6 years in 1986, the proportion declined to 30% in 1991 and 2002. Market demand, client or parent company demand began to play a clearer role in influencing companies to enter into the market over time, perhaps showing the emergence of a new market structure where there was none before. The proportion of companies that specialized more than 80% of their sale in optoelectronics increased from 12% in 1986 to 27% in 2002.

Table 6 shows interesting trends in major issues identified by the companies. Whereas they saw human resources as the key bottleneck for further R&D (98%) as well as for business development (82%) in 1986, only 40% and 60% of companies saw human resources as the main issue for R&D and business development in 2002. This raises questions about whether human resource constraints were one of the key factors that constrained new entry and business conversion into optoelectronics, dampening interest among companies. In contrast, identification of user needs increased sharply as an R&D issue from 33% in 1986 to 72% in 2002. Similarly, client and buyers as a source of technical information became much more important from 20% in 1986 to 53% in 2002, with a commensurate decline on the importance of specialized magazines and journals from 93% to 51%.

These appear again to be consistent with the picture of an emerging market and an industry with increasingly closely knit web of companies, though these ties may not necessarily be regional. It is also important to note that even with the said decline; human resources continue

to be one of the major problems that companies face, especially when they think about future expansion and development.

The survey shows no discernible change in the role of universities or research institutes. If anything, they have remained reasonably important sources of information and units with which to collaborate.

Recently, there have been several government initiatives that focused on optoelectronics in Hamamatsu. Learning from the past, they have focused on creating interactions among local players as discussed below.

Semiconductor laser orchestrated by the Chamber of Commerce. The initiative was a research funding for laser semiconductor related research provided under the Ministry of Economy and Trade and Industry starting in 2001. This was a natural extension of activities by a working committee for industrial hollowing organized by the Chamber of Commerce starting 1997. They had identified optoelectronics as a potential leading industrial sector, and proceeded to organize workshops to familiarize local businesses about potentials of optical technology. Because of this background, they were able to move quickly to put together a proposal for funding from the METI when it became available unexpectedly through revised budgets[2]. These early efforts were often criticized by participants: that the workshops were organized by professors whose main expertise lied outside of laser diode technology; that the research proposal was "fabricated" simply to purchase equipment; and that HPK was only remotely involved even though the façade of legitimacy arising from HPK's involvement was important.

Nonetheless, these early efforts led to another development-oriented research lead by a local machinery processing company, Enshu. HPK had bought a small share in Enshu in 2001 announcing the joint intention to work on laser processing technology, and so Enshu's research interest also made sense, and indeed led to a new product introduced in 2003.

Power laser research orchestrated by HPK. The second research collaboration effort was proposed by the HPK through its non-profit research body, in collaboration with several local companies, Osaka University and Shizuoka University and Hamamatsu Industrial Technology Center under the Collaboration of Regional Entities for the Advancement of Technological Excellence by JST starting in 2000. HPK works with 3 other smaller companies, which are all committed to undertaking research and hopeful to get some returns from it.

A former professor from Osaka University plays a central role as a technical advisor for the whole research effort. The project is, in one sense, a logical extension of 30 years of close working relationships between the Laser Institute at Osaka University and HPK, which started initially as a client-supplier relationship with HPK supplying camera equipment. The Laser Institute was undertaking cutting edge research and HPK provided critical support in developing unique instrumentation for the institute. When the Laser Institute could no longer

[2] There appears to be an implicit understanding that funding from revised budgets is often easier to get, if and if only one can move quickly enough to get a proposal together. Time given for proposal development is quite tight because the government has to meet the expenditure targets within the same fiscal year. (check with Fujizue sensei)

obtain funding from the government to continue in internationally cutting edge research, the leading professor decided to move into commercial applications, and the relationship with HPK evolved into one joint research partnership. HPK had provided large donations to fund initial research, and today 3 of their staff are working in the Institute.

The joint research under the Collaboration of Regional Entities Program constitutes another stream of follow-up activities of this long standing relationship, with a greater focus on generating technology relevant for a whole industry to support regional development.

It is not clear that Shizuoka University and Hamamatsu Industry Technology Center bring in similar content expertise that are of central importance to the project. They certainly engage in related projects, provide space and facilities, and making it a regional collaborative effort, however, they do not appear to be the driving force for the initiative.

It looks as though HPK was forced to bring in other companies and organizations mainly to satisfy the requirements under the program. Whatever the initial cause, there are multiple companies seriously committed who are optimistic that there would be substantial technological gains from the initiative. It also provides key exposures to cutting edge know-how of HPK for regional players such as related companies as well as Shizuoka University and the Industrial Technology Center, and may be helpful for regional diffusion of know how for this reason.

The Intellectual Cluster Initiative orchestrated by Local governments and Shizuoka University. The third initiative is the Intellectual Cluster Initiative under the Ministry of Education and Culture, which was just started for funding in 2002. It was the prefecture, city and university representatives who put together a proposal for funding, but they are vociferous about the erratic manner in which the whole project idea changed through the preparation year of 2001. When the ministry approached the city in March 2001 and then the prefecture in May 2001, the idea was to support activities that would lead directly to university ventures, and that this was to be nothing like conventional industrially relevant research projects. As the cities/prefectures prepared their proposals, they found that the Ministry changed its position over the course of the year and by early 2002, they were only willing to support research activities with significant industrial involvement, dropping any notion of university ventures. The interviewees suspect that the Ministry must have met some jurisdictional problems with METI, who had similar ideas on focusing on university ventures. Another major change was in the mechanism of funding. Originally proposed as a grant program from JST, it became a subsidy program directly from the Ministry. This seemingly innocent change was a significant development, because a “subsidy” required substantive funding commitments from local governments themselves. The proposers had to negotiate back in their own agencies for new budgetary support. The proposers suspect that this change arose because of the increasing scrutiny on the role of government periphery bodies by the Ministry of Finance.

The proposers were also asked to justify their overall theme in light of other and on-going initiatives, particularly the Collaboration of Regional Entities for the Advancement of Technological Excellence project. The interviewees explained that it was not easy for them to do so, given that they have little technical background. However, with the collaboration from

the university, they managed to write a proposal that focused on different aspects of optoelectronics – the receiving side, as distinct from the emission side.

These stories indicate how much of the precious preparatory energies of the organizers have been spent on the central government criteria and interest, and how little time they have had to bring the local needs into the planning process. Research activities have not gone far enough to understand how successful the result may be. However, many observers were skeptical of the design of the project discrediting it a civil-servant and university-led initiative.

Today's industrial structure in Hamamatsu. The 2002 survey indicates that there are 5 types of companies in the industry today:
(a) A globally competitive company - Hamamatsu Photonics and their subsidiaries
(b) Nationally competitive specialist companies
(c) Medium scale companies established in other products that entered into the market more recently
(d) Small specialist start-up companies
(e) Small independent subcontracting companies that are entering into optoelectronics by the virtue of their client demand

In the next two sections, technological developments of HPK and other companies will be highlighted, with quick summaries of about regional factors that supported their technological developments in each.

V. Technological developments of Hamamatsu Photonics (HPK)

HPK was founded in 1953 by Heihachiro Horiuchi, a graduate from Hamamatsu Industrial High School (today's Electronics Institute in Shizuoka University). Horiuchi first came to Hamamatsu in 1934 to work with Prof. Kenjiro Takayanagi, who was nationally renowned for his research on television, and formed a lasting relationship both with Takayanagi and his disciples.

It is today a globally competitive technology-oriented company with niche markets in light sensor/emission devices such as electron tubes, photomultipliers, and laser diodes. The company is focused on customized production of highly specialized parts and equipment, and grew steadily over the past 5 decades to become a global leader in a range of products. It is listed in the first section of the Tokyo Stock Exchange, and it has remained highly profitable even during the lost decade of Japan in the 1990s, with its production constantly expanding.

Over the 50 years, their products evolved from being imitations of existing foreign products to becoming cutting edge globally. There has also been a significant change in the level of internal technological capacity. Early trial and error appeared to be nothing more than simple leaning by doing, with heavy involvement of academics from Shizuoka University, and indeed with much experimental work undertaken on campus rather than on company premises. Over time, internal research capacity developed and company staff began to undertake most development activities and related research in-house. Such an evolution of both their products and internal technical capacity can be described in terms of four periods: (a) establishing the basic products and technology (1953-1964); (b) becoming nationally competitive (1965-1979);

(c) becoming internationally competitive (1980-1989); and (d) delving deeper into the realm of science (1990-). The pattern of patenting largely reflect such a trend, whereas there were hardly any patents in the first period, they began to regularly apply for patents in Japan since the mid 1960s, and they became highly active in patenting both domestically and internationally since the early 1980s.(Fig 7)

Establishing products (1953-1965). In the early days, the company established the technological base for producing a range of products, spanning from electron tubes, photomultipliers to opto-semiconductor products such as CdS cell. Though these were products new to the company and to Hamamatsu, there were other companies, most notably in the US, who were manufacturing these. HPK's role was to catch up and master production technologies, including the selection of the right raw materials particularly for electrodes, product design and glass processing techniques. HPK also began to provide instrumentation support for some national research projects, for instance, for developing camera monitors where they were forced to acquire electronic circuit technology. The company engaged in exhaustive trial and error, and managed to acquire a lot of production know how through learning by doing.

However, in almost all of these key technological matters, the company also relied heavily upon the insight and expertise of the Electronics Institute in Shizuoka University. The former CEO had come with an experience of working in a research team of Prof. Takayanagi, and several of his contemporaries were working as junior professors in the University. HPK often got key technological advice, training and access to facilities, such as glass processing. Many of the early employees were trained there, stationed there, and specific faculty members were identified as key advisors in specific know-how. For their first research project for which they managed to get government funding, they asked a Shizuoka University professor to come up with an appropriate research topic and eventually appointed him as the principal investigator, with their employees working with him. Apparently, they did not have an internal capacity to lead a government sponsored research project at this stage.

Becoming nationally competitive (1965-79). This is the period when HPK's products become nationally competitive, with their technical expertise beginning to be recognized by key national agencies. They began to work for key technology development projects to supply optical measuring instruments such as motion monitoring precision cameras, as well as specialized light emission devices, which not only added to their range of technical know how, but also enabled them to work closely with national players such as national research institutes, defense, or national universities. Working closely with leading academic researchers for their instrumentation needs enabled them to absorb basic knowledge around the instruments through client professors. HPK also started large volume production for selected products such as opto-semiconductors and low grade photomultipliers, which required them to expand their factories, and establish greater reliability in their manufacturing, for instance by establishing a specialized glass processing plant. Fortunately their expansion plans throughout its history took place quite smoothly as they readily identified land of desirable size and location either from other companies, or from local governments developing new industrial estates.

They were increasingly relying upon internal teams and experimentation as a source of knowledge and know-how, while their scientific contacts from whom they obtained technical advice expanded to include national experts from key national laboratories, ministry research groups or national universities. Professors as clients appeared to have played a particularly significant role, as they often became personally engaged in their equipment and instrumentation, spurred by their individual research ambitions. While HPK has made use of client companies as a source of knowledge, there is little evidence of structured collaboration, except one case where Hitachi asked HPK to purchase its factory on optoelectronics parts. By this period, significant research projects funded by governments were all led internally by their own staff.

Becoming internationally competitive (1980-1990). This is the period when HPK came up with a number of global first, and established their reputation as a leading technological company. For instance, they developed specialized and world's biggest photomultipliers sensitive enough for neutrino detection, at the request of a professor from Tokyo University, who later won a Nobel prize for this research. They also came up with specialized photomultipliers for positron emission tomography (PET) which advanced medical examination significantly, and helped them to have the largest global share in this area. They also won international awards and acclaim in specialized technologies such as ultra-fast streak tubes as well as photon counters.

While their research style remained heavily geared towards intensive experimentation and internal work, HPK during this period also established much greater contact with both national and international scientists. They recorded communicating with and soliciting advice from foreign universities at key junctures for their work.

One noteworthy relationship during this period was one with Hamamatsu Medical University. In order to enter into a new area of medical applications, HPK developed very close ties with multiple academics in Hamamatsu Medical University. Semi-annual Medical Photonics Meetings were organized for their staff to meet with university academics. A typical meeting comprised several presentations by the university academics and HPK staff, as well as external speakers, and brought together about 50 people from the two communities. One HPK staff recollects how it was like learning a foreign language at the beginning. There were about 10 of such meetings, which were later developed into other activities around an endowed chair by HPK, which helped Hamamatsu Medical University establish a medical photonics center. For HPK, working with Hamamatsu Medical University provided a helpful opportunity to understand medical user needs, as their academics were also clinical practitioners at the university hospital.

Delving deeper into the realm of science (1990-). In the 1990s, HPK became more forward looking in their technology development, with explicit and systematic effort made in a range of frontier science through their central research laboratory which was established in 1990. In 2002, HPK spent 14% of its total sales revenue on research and development, with 15% of their total employees or 360 staff dedicated to R&D, of which 31 were PhD holders (including 8 who obtained their doctorate through corporate research). One example is their work in laser diode. A major collaborative initiative was made with Osaka University's Laser Nuclear

Fusion Research Center on laser diode, with HPK endowing a chair in 1996 and sending their staff there to work on collaborative research projects. It has developed clinical facility for further research on PET, with professors from Kyoto University recruited to undertake the task.

Another change was the aggressive manner in which HPK established five key collaborative relationships with specialized companies with complementary technologies starting in the late 1990s, three with Japanese companies all over the country; one through acquiring an American company; and one with Enshu, Hamamatsu-based machinery manufacturer, through which they have jointly developed a global first in laser processing equipment.

HPK has also been orchestrating a government funded research collaboration project on power laser diode since 2000, which was also used to support further collaboration with Osaka University, but where collaboration with other Hamamatsu-based companies was required by the government funding source. These appear to be the first major technological involvements with other local companies for HPK.

The CEO has developed a wide range of ties with cutting edge scientists around the world and nationally also. They have only as many projects with foreign partners as they have had with Shizuoka University or Hamamatsu Medical University respectively. However, they spend more money in foreign universities than in Japanese universities, showing how much they value these partnerships. One example of their commitment to keep connected with international science is an international conference series hosted by HPK on the Mind Brain Peace Conference, where world renowned scientists are invited to explore the frontier of science.

Hiruma, a idiosyncratic leader of HPK, who has a first hand experience of working with a range of university professors in Japan and globally in the last 50 years, has a clearly defined view as to what he can obtain from domestic academics and international ones. They learn "KAGAKU" from the Japanese professors. Kagaku is a Japanese word for science, but he explains it as an activity of organizing knowledge by subject and convenient category which is very helpful for learning. Japanese professors are good at such an activity. However, when they need to explore the cutting edge of science, they go to selected foreign scientists. It is his firm belief that the institution of science as exists in the West never took roots in Japan perhaps except for some outstanding individuals.

One thing that remains constant throughout the history of the company is the intensive process of trial and error. It is so intensive that it often sounds like a mindless exercise of trying every imaginable combination. Over its history, what HPK learned and came to believe is that breakthroughs often take place outside of what is known in science. Indeed there are specific instances where HPK as a late comer managed to outperform the incumbents simply because they pursued options deemed infeasible by the incumbents out of ignorance. Hiruma, is a harsh critic of learned graduates from Japanese universities who tend to say that things cannot be done because existing scientific knowledge dictates against it.

While he criticizes scientific learning and preaches to go beyond it, he is also well known for pushing every employee to study hard and keep abreast of scientific progress. He himself is an avid reader of scientific journals, and will habitually demand his staff to read as much and think about their implications. The company philosophy is one of pragmatism to make use of every piece of scientific and technological information that is available, while not taking those for granted.

Their ties with the international scientific community do not mean HPK has abandoned the relationships with local universities. They still have at least one staff stationed in Shizuoka University at any given time, and use their expertise whenever relevant, though direct recruitment of graduates is today insignificant at only a handful 2-4 in a batch of 40-50 a year. They continue to host medical photonics courses along with Hamamatsu Medical University. About 20% of their research projects are with these local universities, with the Central Research Laboratory having slightly more projects with Hamamatsu Medical University and the operational groups having slightly more projects with Shizuoka University.

It appears as though HPK today has a stabilized structure of being connected to different types of university academics for different purposes. Shizuoka University is no longer the main source of recruitment, though they can provide important inputs for staff training and information gathering on a day to day basis. Hamamatsu Medical University appears to have been particularly important for HPK to develop better understanding of medical needs, a new area of work for them. They began to rely increasingly upon universities all over Japan for key client relationships from where they learned about user instrumentation needs. They are today solidly connected to cutting edge scientists to understand the general directions in key fields of importance.

The role of the region. What benefit did HPK receive as a result of being located in Hamamatsu in its technological development? The first regional influence came in the form of pervasive technological inputs from Shizuoka University's research groups who played a pivotal role in shaping HPK's early technological base and in catching up with the rest of the world. The university also played an important role as a source of graduates, although its proportion declined over the years. HPK's relationship with the university continued well into the present, but perhaps with their influence less pivotal in their technological progress, and their contribution dwarfed in light of other technical inputs they obtained from national and international researchers and scientists.

HPK never grew into a massive company, but did have its own expansion needs at key junctures, and were able to relatively easily identify appropriate factory sites, from government led industrial estates or by buying from other companies. The fact that they never needed to look elsewhere shows that the company's basic needs in physical and human resources were satisfied by the region.

HPK never had major suppliers or clients within the region, other than with its own subsidiary companies. Indeed HPK tended to be vertically integrated in its production, and did not foster much of a supply chain. This image of isolation has been changing in recent years as HPK

engaged in a collaborative relationship with Enshu on high power laser processing equipment, and in a research project with a handful of local suppliers.

It is not clear what has brought about this change. On the one hand, HPK was said to be grudging when the government required them to have collaborators on the government funded project, preferring to have gone alone. On the other, Hiruma, HPK's president has also been increasingly conscious about giving back to the regional community. It is not clear how Enshu developed its initial interest in laser processing, but on-going regional optoelectronics initiatives orchestrated by the Chamber of Commerce led to Enshu winning funding from METI as a follow-up project. This in turn provided the requisite push in their collaborative project to develop high power laser processing equipment with HPK. Government support and their conditions for collaboration appear to have helped in fostering local interactions.

Hamamatsu Medical University has been working closely with HPK since the 1980s in a more visible way than Shizuoka University. First, they worked with HPK in orchestrating semi-annual seminar sessions where HPK staff learned about medical applications, an area foreign to them to begin with. They have also been collaborative through the establishment of the Medical Photonics Center through an endowed chair by HPK, introducing a new field in their research and teaching.

VI. Technological developments of other companies

What were the technological developments in other optoelectronics companies? In this section, five types of optoelectronics related companies are described in terms of their development experience, in order to understand what regional factor, if any, contributed to their development. One case of a recent start-up is also described, although it is not in optoelectronics, as an unusual case which comes close to being a university spinout, to understand the dynamics at work at the boundary of the Shizuoka University today.

Domestically competitive specialist company. Company A is the only other specialized optoelectronics company in the region which is listed in the second section in the Tokyo Stock market. It specializes in on optical pick up equipment for CDs and DVD related devices. It started in the 1969 a spinout from a subsidiary of HPK, but its founder firmly states that its technological focus in optical equipment has little to do with HPK, and that it has had no commercial ties with them. The founder recalls how HPK refused to collaborate with them when they proposed in the early years, as HPK was not interested in developing down-stream products. The most important source of learning came from a large electronics company, a client for whom they had to produce specialized equipment. However, he recounts the difficulty of trying to learn from the client electronics giants, because they were constrained heavily by the clients' intellectual property conditions. They had to be innovative in their learning strategies – attending commercially available conferences and workshops; working with retired employees of other major manufacturers and so on. The founder feels strongly that they gained little from the Faculty of Engineering in Shizuoka University even though he graduated from there, or other local companies, either clients or suppliers.

He recalls that they relied heavily upon mid-career recruits in the early years, as they needed skilled people with basic understanding in the field. They had little contact with Shizuoka University even on recruitment.

The only instance he recalls where he gives credit to the university is when a new professor with industry experience started a technology forum where key industry players were invited. Through attending such a forum, he developed key contacts with another electronics giant, which led them to have a breakthrough opportunity to set industry standards.

Mid-sized late comer. Company B is a specialty electrical material company, established in 1970, which began to produce optical fiber in the 1980s, initially through joint research with another material company from outside of Hamamatsu. The share of its sale in optical technology related products is still quite small. In their experience of technology development, the main source has always been internal experimentation, aided somewhat by information and collaboration from client and supplier companies. The CEO does not appear to see these external sources of expertise as especially significant. However, there is one outside individual whose technologically informed views the company relied upon on several critical occasions. The individual had worked in another major electronics company, but had been introduced to him as an alumnus of Shizuoka University. Today, the individual is retired from the electronics company and works as an advisor/consultant for Company B and continues to give informed advice on technical matters.

Shizuoka University graduates dominate their engineers, with 40 out of 120 coming from Shizuoka. Such dominance appears to be a legacy of the past as only 10-15% of their annual recruitment comes from Shizuoka University today, with the majority being graduates from other universities returning to their homes in Shizuoka. They recognize that the alumni group provides an important networking opportunity for interaction with other engineers outside the company. As to a more specific role of Shizuoka University for their technological development, there are divergent views. The CEO is adamant that Shizuoka University has not been helpful, and points to the fact that they do very little research that are relevant to their technological needs, and that their professors are not at the cutting edge.

Their R&D director, on the other, notes that even though Shizuoka University does not offer the central technical solutions for Company B, they have a range of helpful professors who work in sufficiently relevant fields, with their willingness to work with companies becoming stronger with recent national policy emphasis on university-industry relationships. He found that he still has to make a lot of effort searching for expertise, but that when he does, he is usually rewarded with helpful inputs from them. He gives examples of joint research projects, or seminars being provided to a wide group of employees. Another professor has been invited to the company to give some generic lectures to staff on the basics of electromagnetic waves. He speculates that perhaps Shizuoka University is right for them given their level of technology. He does wish that Shizuoka University would make it easier for small and medium scale companies to approach them by lowering price expectations for joint work, or by developing better mechanisms to allow their technicians to offer services outside. For instance, Shizuoka University has very good glass processing technicians, but it was very difficult to arrange them to be able to help them. This is an interesting complaint, since HPK

used to rely heavily upon the glass processing capabilities of Shizuoka University until they built their own plant in 1970.

Company B started supplying light guides with optical fiber to HPK recently, and has also been invited by HPK to participate in the government-funded regional research collaboration project on power laser diode. They are finding the research collaboration a useful opportunity to be exposed to research methods of HPK, and see it as an important opportunity to develop their technological capability even if it does not lead to commercial products.

Specialist start-ups. There are about 10-15 known cases of HPK employees leaving HPK to start their own companies specialized in optoelectronics. Two companies interviewed were examples of such cases, one with a 12 year history, and another with only 5 years. Even though they are new companies, because of their former experience in HPK, the companies started out with high technological know how on the production of specialized and customized optoelectronics equipment. One company is specialized in testing equipment for universities competing against foreign ones, using closer location and ability to customize as their comparative advantage. The other company produces customized equipment for research groups of large manufacturers. Both of them have expertise to come up with patentable technology in-house.

For them both, user needs are critical sources of technical information. One of the CEOs finds that when his manufacturing clients saw that he had virtually no manufacturing capabilities, it became easier for him to obtain sensitive information from them than he ever did in HPK. Whereas HPK could turn into a competitor easily, a small start-up cannot, so these large companies are more ready to engage in confidentiality agreements and open up. The other finds that working with university researchers who are interactive helps him discern the key needs. Interestingly, neither of them today works with HPK, even though one company started out with many sub-contracting type activities. Another admits that HPK was not happy to see him leave the company and that has prevented him to establish commercial ties with them. Instead, he often operates on the basis of a loose network of similar small companies, mainly other start-ups from HPK, where they join forces to cope with specific orders. The network is also sustained by several trading companies who operate as a matching device for connecting user demand to producers and for bringing together complementary producers.

Neither of them finds Shizuoka University as an important source of information or graduates for recruitment. The older company has remained extremely small, with only 2 mid-career recruits. The new company has already begun to recruit nationally and intends to continue to do so. They are able to keep up with the central technological needs through reading related journals/magazines and attending conferences and loosely networking. One of them relies upon the prefecture operated Industrial Technology Center, which has an optical group, for key and expensive testing equipment that appear to be otherwise under-utilized.

Small subcontractors. The two subcontractors interviewed were specialists in precision metal processing and specialized power supply units. They were both small with less than 100 employees, the majority of whom come from local specialized high schools. Both were

recognizing the need to upgrade their technical capability to meet increasingly cheaper foreign competition.

Neither of them worked exclusively for a single company. One had an explicit policy to diversify clientele and the other worked for a large musical instrument company and selected to work for HPK, which was clearly not competing with the other client. More generally, Hamamatsu is full of such specialist subcontractors, many of which fall into keiretsu of larger companies such as Suzuki, Honda or Yamaha, though these keiretsu affiliations are gradually weakening as companies adopt globalization strategies. Indeed, one of them was beginning to subcontract with China for smaller parts, themselves beginning to specialize in technical design. The need to upgrade their own technical capacity was genuine, the reason why both of them agreed to participate in the government-funded HPK-led research project since 2000.

They acknowledge that when they have technical problems, they rarely resort to external help – the only recipe being that they take the time through internal discussion and trial and error. They learn from brochures of other companies, exhibitions, but rarely do they find published materials that are of use to them.

For them, Shizuoka University represents technical expertise that is irrelevant, even though one of the CEO is a graduate from there. They recognize that their activities are probably too old fashioned for any university to be doing any work in, and their graduates are far too high powered to be attracted to employment opportunities such as theirs. The Shizuoka graduate CEO explains that he basically inherited his family business and is an exception than a norm in the company. However, he acknowledges that alumni network has been extremely helpful for his business, and that his relationship with HPK developed from with an order from a fellow graduate who joined HPK. They both use the prefecture's Industrial Technology Center and find their testing equipment helpful.

A university start-up. The software company was established in July 2001 as a rare case of a university start-up (they think that they are about the only recent university-start up since they are constantly invited for speaking engagements in the university as a model case) from Hamamatsu Campus of Shizuoka University.

The founding CEO of the company describes four critical moments in the company development thus far. The first case was his exposure to the Silicon Valley as a student intern, which made him convinced that he could start up himself. This internship opportunity was made possible by a professor with industrial work experience who had sufficient industrial contacts from his working days to introduce him to a company in the Silicon Valley. The second one was getting together with two other founding members, both of whom he had met through his student years at the Faculty of Engineering. One had left Shizuoka upon graduation, but they had kept in touch, and were aware of each other's technical interests and experience. The third was meeting a key client in Hamamatsu, again through the introduction of the same professor. The fourth was meeting a professor from Tokyo University, who introduced him to key people who had technical appreciation of the product that he wanted to develop. He was visibly excited about these recent encounters, as it was the first time he could talk about his dream product to outside experts.

Interestingly, the CEO feels he owes little to Shizuoka University, in spite of the fact that all of his key contacts came from there. This lack of appreciation for the university may arise from the fact that the university did not provide much inputs for the technical know how that he needed for his company. His doctoral thesis was only marginally relevant to the work they are aiming to do – there were no technological seeds that he picked up from the university.

The role of regional factors. What benefit did these companies and their technological developments gain from being in Hamamatsu? The most significant factor appears to be the industrial base from which they grew. All three specialist optoelectronics companies had directly or indirectly spun out of HPK, suggesting that the very existence of HPK has had an influence upon the region, even though HPK is known for its life employment tradition and has not encouraged spinouts.

The other companies sprung up as part of a diverse manufacturing region, benefiting from trades that existed in the region, at least while they are small or at the outset. One of the spinout optoelectronics company was using a loose network of similar companies from the region as a base upon which to respond to orders that they by themselves could not do. Various business contacts such as trading companies that come and go through diverse manufacturing regions such as Hamamatsu provide them with good business contacts to start with.

Recently, there appears to be more local relationships emerging around HPK. This is partly because of HPK's change in its technological strategies as it gives greater emphasis on collaborations with specialized companies generally. It is also partly because of the government mandate for HPK to collaborate with local companies, as a condition for their generous research funding.

They also appear to have benefited from ability to recruit engineering graduates from Shizuoka University, albeit to varying degrees. Small subcontractors found that they were unable to recruit graduates except for leadership positions. Also when companies develop national reputations, they become less restricted to local recruitment. One company explicitly noted that their ability to recruit mid-career engineers helped them during the early years.

Similarly, most of them noted that they made use of testing equipment at the Industrial Technology Center, particularly when their size does not permit them to have such instrumentation in-house.

There is a certain pattern of their dependence upon the regional resources: the degree to which they draw on regional resources is different depending both on their reputation/aspirations and the size. All have benefited from regional resources, particularly the industrial base of the region, particularly when they were starting out. For small companies that are competitive locally, such as the subcontracting companies, the Industrial Technology Center continues to be important throughout their lives, and their ability to draw on university inputs either for graduate recruitment or research is highly limited. For those companies that have aspired to

become nationally competitive, local recruitment of graduates or mid-career engineers has been important.

VII. The role of universities and public institutes

These development paths of optoelectronics companies collectively portray several distinct levels of technological needs and capacity. Locally competitive companies were based on local graduates, often more from local high school than universities. They tend to have little scope for technological improvement in-house. Nationally competitive companies, or those that aspire to such a status, on the other hand, often recruit graduates locally and nationally to develop higher caliber internal capacity for technological development. When companies become internationally competitive, they rely increasingly upon nationally recruited graduates and postgraduates, and require contacts with both global clients and scientific community to keep abreast of technological progress.

The nature of external inputs needed including human resources and technological information and the manner in which they would interact with external entities appears to depend on both the level of their product sophistication and internal technological capacity.

Recruiting. There is a kind of equilibrium between the level of product/technological capability, reputation and the level at which the companies recruit. For small low tech companies, recruiting graduates is not easy at all. For companies that are aspiring to improve its product/technological capabilities to become nationally competitive, it is important to recruit graduates, and they are more likely to be able to do so from local universities at the outset on the basis of their local reputation, as HPK did in its early days or as Company B did until recently. As companies develop national reputation, and sometimes they do so strategically through going public as two of them did, they will be able to attract graduates from national graduate markets. Ability to recruit appears intricately related to visibility of the companies. Since it may be easier for companies to become visible in the local environment, local universities play a particularly important source for recruitment.

The experiences of these companies illustrated that any company that aspires to be nationally or internationally competitive requires a constant supply of technological information. Interactions with clients and suppliers are critically important for their technical innovations, but they are also highly restricted avenues because of corporate secrecy. When the company is small with limited manufacturing capabilities, it is possible that large client companies will be more likely to lower the corporate walls, because they are not threatened by small companies stealing their know-how. However, as they grow, particularly if they remain independent and resist the temptations to join keiretsu, they have limited avenues for acquiring technological know how from such sources. This was where universities and public research institutions appear to come into play.

Specifically, there were six mechanisms through which universities and public research institutes locally and globally help companies penetrate the corporate walls: alumni networks; professors as facilitators of industrial contacts; professors as sources of technical information; professors as interactive clients; and professors as star scientists. These categories are

presented in an order to show progressively hands-on role universities can play. It is important to note at the outset that some roles appeared to be important for all types of companies, while others were more critical for companies that were aspiring to compete globally at the technological cutting edge.

Through alumni networks. Alumni networks were visible in many of the key interactions that made a difference to companies. Friendships appear to create unique private interaction space, where individuals are willing to talk as individuals, perhaps dropping a little the company guard that one puts on under normal professional circumstances. The dense alumni networks can also form a basis for business interactions that can lead to contracting and other business relationships.

Professors as facilitating industrial contact. There were many examples where professors provided key information as to whom else to contact, even though the recipients of such services may tend to discredit the value of such facilitation.

Professors as sources of specific technical knowledge. The academics can help in education and training by organizing the relevant knowledge available in the public domain. They can impart such expertise through seminars, or classes or more narrowly through joint research activities. However, the relevance of their expertise appears to depend critically upon the difference between the level of their expertise and that of the companies. In the extreme scenario, companies may have better know how in some areas and may not find university expertise helpful. In another extreme, university professors may be working on problems that are far too sophisticated for the companies. Somewhere in the middle, it is also possible for university professors to help companies learn the underlying science at a more general level particularly for employee training.

Professors as clients and open discussants. In some cases, academics not only provide specific technical know how but become involved in a protracted way where they play a discussant role. This was a key role that HPK relied upon heavily throughout its company history, perhaps in part owning to their specialization in instrumentation, where university professors were obvious clients, who, unlike corporate clients, were willing to engage in discussions.

Professors as a source of strategic technical advice. Professors can engage in setting corporate strategies for technological development, by providing their knowledge of what is happening at the cutting edge of technology and by providing relevant contacts (even without themselves being involved in the creation of cutting edge science). This is what Electronics Institute faculty members appeared to have done for HPK, in their early days. The Electronic Institute researchers were well informed of technological progress abroad, and even if they were not directly participating in the creation of cutting edge science themselves, they were able to provide such information to HPK. Their inputs were critical in HPK setting its strategic directions.

Professors as "star scientists." Contacts with professors engaged in cutting edge science can help companies get a better sense of the scientific and technological frontier that are in the

making. This is what HPK appears to be doing today in its global network of scientists. Their inputs appear less direct and tangible, but important in keeping a perspective for the way forward for a company that aspires to remain at the cutting edge.

VIII. The role of local universities

The Hamamatsu case appear to show that Shizuoka University used to play a higher order role as a source of strategic advice to HPK, but does not appear to do so today. They are bringing in retired professors from Osaka or Kyoto for such higher order activities, and appear to be relegating Shizuoka University for more routine learning. Hamamatsu Medical University, on the other hand, appears to be playing a greater role as professors as interactive users/clients. This raises two related questions: (a) why does Shizuoka University today appear to play such a limited role? (b) Why does Hamamatsu Medical University appear to play a more important role for HPK even today?

One possible explanation is simply that HPK outgrew Shizuoka University by becoming internationally competitive. The professorial roles to be played by local universities depend on the relative levels of their technological capability. For globally competitive technological companies such as HPK, their key needs can be met only through international star scientists in the relevant fields.

Also, Shizuoka University appears to have placed declining emphasis on relationships with industry over the years, until the late 1990s when the central government drummed up support for university-industry relationships. This may explain why Shizuoka University became less important as a source of start up companies or as a partner to lower-tier technology companies such as A and B. Indeed, there are several historical factors that are likely to have made the university less dynamic in its relationship with industry. First, the Faculty of Engineering was adversely affected firstly at the end of WWII and secondly through student uprising and various movements in the 60s, which dictated against firm ties either with the government or private industry. Takayanagi's TV research was even "purged" for a short period after WWII by the occupation government, as military research. The student uprising in the 1960s did not have a direct effect on the Faculty, but impacted the wider university mood with respect to close ties with private capitalists. The faculty subsequently had greater problems in getting university-wide endorsements in its aspirations to collaborate with industry.

The second related factor is that the Faculty of Engineering, which used to be a free standing Industrial High School, later became amalgamated as part of Shizuoka University in 1948, which was a policy imposed by the central government as part of the occupation government's educational reform agenda. The faculty had to come under a broader university governance structure, which often worked against the engineering group to do what it wanted. All joint research proposals were subject to approval by university-wide a committee, which often meant that they met cynicism and criticism for working with industry particularly from humanities and arts faculties. They were not able to put forth plans without having to fight competing interests from other campuses. One engineering faculty who has been observing the recent process of establishing a technology licensing office, noted that it would have been far easier, had they a university president who was also an engineer. It was not easy for the

Faculty to work with a leadership from another subject area, and being a remote campus away from the administration. Becoming a university also meant that new values about academic work and publications became more important, often at the cost of industrially relevant work.

The governance problems voiced by the Faculty is echoed by Hamamatsu Medical University's own reflection that they have by and large managed to do what they wanted, given a single subject focus of the university. Strangely enough, the history is about to repeat itself in 2004, as the government makes all national universities to become independent legal entities, and as the government made it clear that the total number of national universities was expected to decline substantially through mergers and amalgamation.

Third, the internal dynamics between the Faculty of Engineering and the Electronics Institute may have worked against dynamism of either. The Institute of Electronics was clearly better endowed, basking in the glory of Takayanagi, and became reputable as the first full-fledged Institute outside of old imperial universities. Compared with them, the Faculty was a poor cousin, and therefore there was considerable jealousy and antagonism against the Institute. Given that the Institute was a research organization, which had to rely upon a supply of students coming through the faculty, this institutional jealousy may not have been conducive to healthy development.

Fourth, there may have been a subtle change in the kind of students they attracted over the years. Older faculty members do recall that in the older days, there was a more diverse student body, including some outstanding students. They lament that today's students are good on average, but there are fewer outstanding ones. In the absence of hard pieces of performance evidence, it is hard to separate "the good old day's syndrome" from the real happenings. However, there are corroborating developments. The mobility of university students has increased in general, and the national entrance examination system has made it easier for students to target specific universities to meet their academic achievement level, reducing the variance among a student body in most campuses.

As for the difference between the Faculty of Engineering of Shizuoka University and Hamamatsu Medical University, there are two factors that are likely to be of critical importance. First, medicine as a disciplinary community tends to have distinctly different relationships with external communities, particularly when linked directly with university hospitals. Professors are also clinicians, and are therefore likely to be interested on technological developments, purely from practitioner's perspectives. There are also clinical trial requirements which make many medical departments close ties with pharmaceutical companies. One HPK staff pointed out that working with Hamamatsu Medical University was one way of understanding how doctors thought and what they wanted – a way of getting close to the end-clients. Second, Hamamatsu Medical University was established much later in 1974, by which time, the fury of student movements had subsided, with the social mood that negated demands of militant leftists. Developed as a single faculty university, it was far less prone to criticism in working with industry.

IX. Concluding remarks

What is the story of optoelectronics in Hamamatsu? It is a story of a new industry emerging, initially as a single company spinning out of a local university, and then with other companies joining. Although it appears to have grown into a sizeable sub-sector of the economy today, there has been little evidence either of dynamic growth or interactions among key players – at least until recently.

What were the factors that inhibited interactions? The corporate side stories remind us of the images of Route 126: hierarchical and vertically integrated firms, lifetime employment and little labor mobility, and subsequent lack of corporate spinouts.

Alumni networks provided one of the few mechanisms through which local companies sporadically came together. Local observers point out that proactive technological coordinators such as public research institutes or university professors were missing to get corporate parties to come together on a routine basis. Hamamatsu's Technopolis never attained the hoped for dynamism owing to the lack of public institutions providing hubs of interactions. Shizuoka University could not meet such a need because its own institutional environment demanded it to become more academic in its orientation, and more isolated from industry.

There are signs of fledging interactions in the region in the past 5 years. The change has been brought about in part by the change of technological strategy of the major firm, which now engages actively in technological partnerships with other specialized companies with complementary skills. It was a result in part of the government incentives for regional collaboration. The good news is that the sharing of technological innovations is beginning to happen within the region. The bad news is that it is an expensive enterprise, and it is not clear that the resulting level of interactions is commensurate with the level of resources going into the sector.

Are the government incentives for regional collaboration enough? The evidence presented in the paper points otherwise. There are two issues. First, most of these programs come with central government conditions and priorities that may in fact be distracting to the regions. More specifically, centrally designed funding programs are often based on half baked directives, or demand too quick a turn around to meet budgetary year needs, leading to less well prepared proposals. Clearly, nationally orchestrated programs need to be stabilized so that the proposal solicitation process and the subsequent evaluation provide incentives for well thought through proposals, rather than quick fixes based on fictitious stories to meet central preferences.

Second, it is not easy to orchestrate such regional efforts effectively, as they require considerable content knowledge on the specific aspects of the technology. There have to be local and neutral players who are capable of coordinating such efforts, and this is in short supply. The fact is that there is no-one other than HPK in the region to take a credible lead in technological development in optoelectronics. Local governments lack specialized human resources who understand the underlying technological issues. The Chamber of Commerce appears is not well structured to cope with new technologies that existing companies do not possess.

Looming large is the absence third party players such as Shizuoka University. The question is why Shizuoka University demolished its optoelectronics group, when it was such an obvious option for both Hamamatsu Medical University and the Industrial Technology Center? Had they amassed key professors in relevant fields of optoelectronics, they could be generating graduates and post graduates with relevant skills, thereby easing the most critically felt constraints in optoelectronics in the region, particularly for the aspiring mid-size firms. These professors could also have played a critical role in orchestrating regional joint research initiatives, involving greater numbers of companies. This missing role is one that could have made the university be the engine of growth for the emerging industry.

A more important question is what can Shizuoka University do in the future to strengthen its role? The first step would be to recruit professors in the areas of relevance and then to form a more cohesive research group around optoelectronics. They should be wooing HPK to give them a chair around which to develop such a group, and to attract the best in the country to come work in Hamamatsu. They should also not shy away from asking HPK to provide key informational inputs and opinions in bringing in such human resources.

They could provide short and long courses geared for company professionals, and may even provide them as modules leading for master's degrees. These would provide greater opportunities for working engineers to meet each other in a setting that make them communicate better.

Whatever Shizuoka University decides to do, the window of opportunity open for them is very slim today. If they move fast enough HPK may still be interested. If not, they will likely form their own university – a noble enterprise but that may be so much harder than working with a university with established infrastructure.

Was it an irreparable mistake for Shizuoka University not to have coevolved with HPK? While doing so would have certainly opened up different types of technological possibilities, the critical failure is not so much that they did not co-evolve, but that they became isolated from the rest of industry as well.

What are the lessons for other regions? The most critical lesson is that every university has implicit target industries by the virtue of the standard of its scientific sophistication. If it is low, it can only help out low-tech industries that are competitive locally. If it is high, it may be able to push the local industries make a transition to becoming nationally and internationally competitive. The important lesson is for the university to remain engaged with industrial needs and to remain engaged to be able to coordinate regional conversations.

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Table 1. Economic change in Hamamatsu

	1960	1970	1980	1990	2000
Population	337,645	439,035	495,200	568,115	589,218
Employment	167,960	230,760	248,743	294,228	310,814
as % share of total					
Agriculture, forestry and fishery	19.6	11.0	6.6	4.5	3.6
Services	39.1	42.4	49.0	52.3	56.2
Industry incl mining, construction	41.3	46.6	44.4	43.0	39.2
Manufacturing employment	62,465	93,969	91,672	103,984	95,071
As % of total employment	37.2%	40.7%	36.9%	35.3%	30.6%
Registered foreigners		1,687	2,221	3,666	18,591
No of industrial businesses		4,473	6,050	5,667	4,395
Manufacturing sale (yen)		410,209.00	1,326,809.00	1,938,493.00	2,016,425.00

Source: Suji de miru Hamamatsu-shi 2002

Fig 1. Hamamatsu population and employment

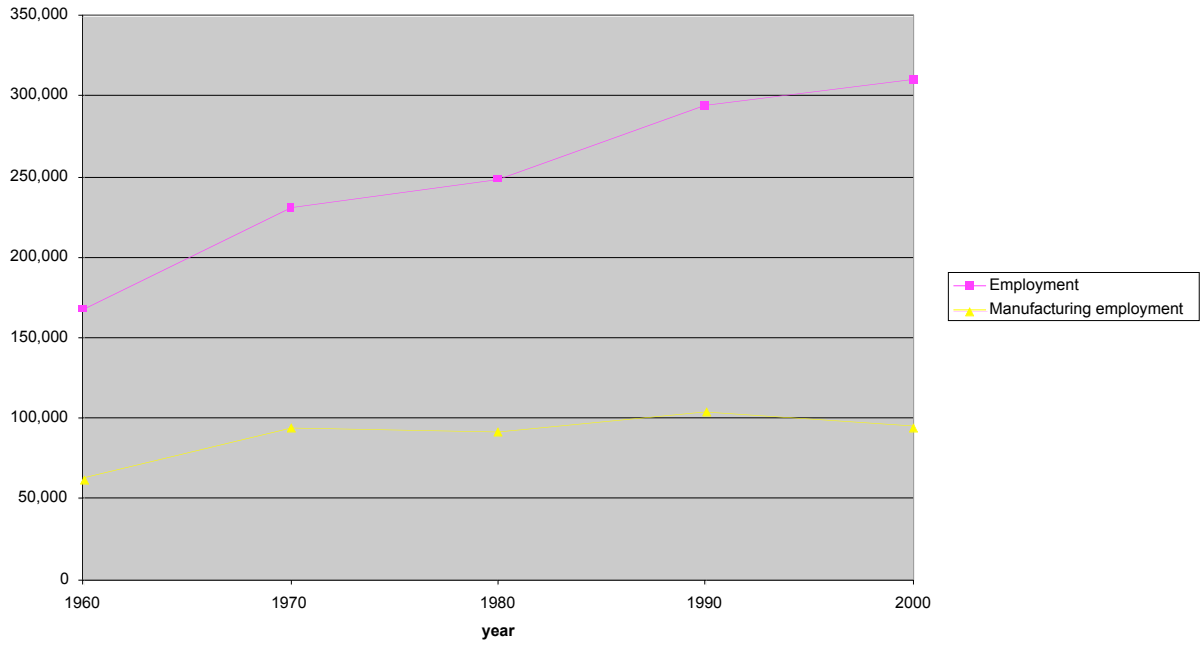

Table 2. Manufacturing sub-sectors in Hamamatsu

	1970	1980	1990	2000
Manufacturing sale	410,209.00	1,326,809.00	1,938,493.00	2,016,425.00
Textile	13.4%	7.7%	4.3%	2.1%
Metal products	6.8%	7.2%	5.4%	4.0%
Machinary	6.1%	5.7%	8.9%	6.4%
Electrical equipment	2.1%	4.3%	6.7%	8.0%
Transport machinery	30.3%	31.7%	37.0%	46.7%
Musical instrunet	18.9%	12.4%	10.0%	9.8%
Other manufacturing	22.4%	31.0%	27.7%	22.9%
Number of businesses	5,412	6,050	5,667	4,395
Textile	38.0%	25.3%	17.1%	11.5%
Metal products	13.2%	12.4%	14.0%	14.0%
Machinary	7.4%	10.2%	13.0%	14.5%
Electrical equipment	0.8%	2.9%	4.9%	5.4%
Transport machinery	6.7%	12.9%	12.7%	14.9%
Employment	91,427	84,044	83,124	70,864
Textile	23.5%	13.5%	8.3%	5.1%
Metal products	9.6%	8.9%	8.3%	7.7%
Machinary	8.4%	7.5%	9.8%	9.4%
Electrical equipment	1.4%	5.4%	8.6%	8.3%
Transport machinery	12.9%	22.3%	25.7%	31.5%

Source: Suji de miru Hamamatsu-shi 2002 and Hamamatsu statistics various years

Fig 2. Manufacturing sale

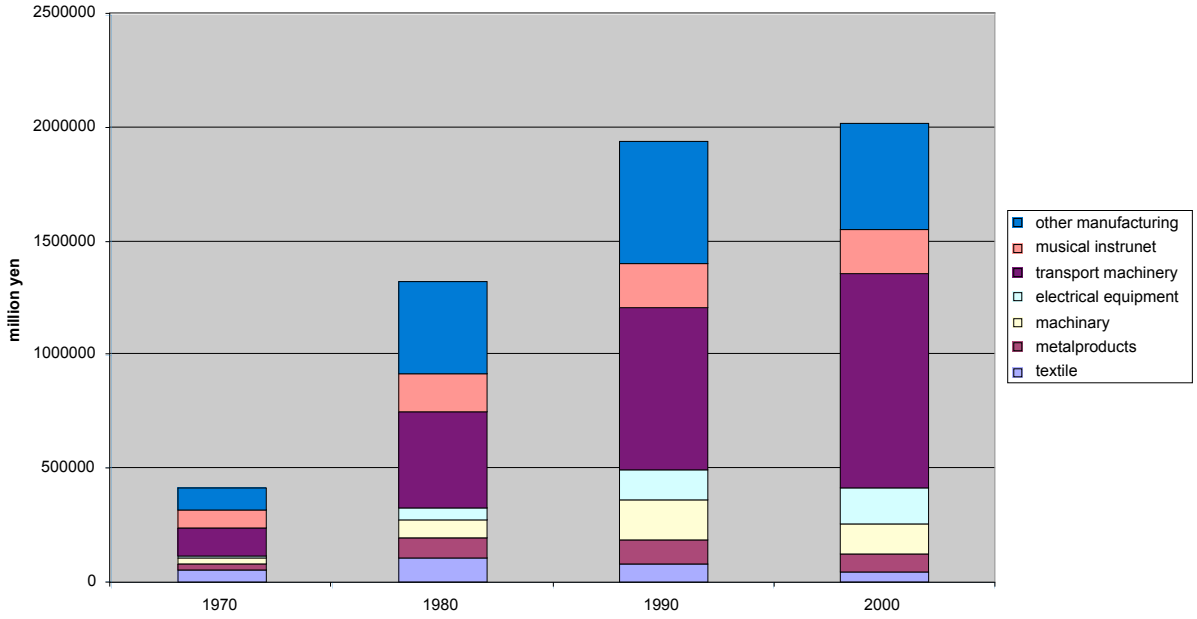

Table 3. Rates of new business start ups, closures and business change in 10 metropolitan areas

	Hamamatsu	Sapporo	Sendai	Keihinyou (Tokyo)	Chukyo (Nagoya)	Keihanshin (Osaka/Kyoto)	Hiroshima	Kitakyushu	Okayama	Kumamoto
Rate of new business start up										
All industries										
91-94	4.5	6	5	5.2	4.3	4.7	5.4	5.2	4.6	5.1
96-99	3.8	5.3	4.6	4.8	3.9	4.5	4.4	4.8	3.9	4.1
Manufacturing										
91-94	2.8	4.5	4	3.2	2.7	3.2	3.9	4.3	2.5	4.5
96-99	1.8	2.8	2.3	2.3	1.6	2.1	1.9	2.5	1.6	2.3
Rate of business closures										
All industries										
91-94	4.4	6.2	4.8	5	4.2	4.8	5.2	5.5	4.6	5.1
96-99	5.2	7.6	6.4	6.6	5.3	6.5	6.6	6.6	6	5.8
Manufacturing										
91-94	4.9	5.2	4.6	4.8	4	4.4	4.9	4.7	4.7	5
96-99	4.5	6.5	5	5.9	4.6	5.7	5.5	5.3	6	4.9
Rate of business change *										
All industries										
survival	87.3	83	86	85.5	88	86.7	84.9	85.2	87.2	85.7
change	0.8	0.3	0.5	0.6	0.5	0.5	0.6	0.5	0.6	0.6
Manufacturing										
survival	91.6	87.1	88.7	90.6	92.2	90.7	88.6	87.9	92.4	87.2
change	1.1	0.2	0.5	0.7	0.5	0.6	0.7	0.5	0.4	0.5

Source: Ito (2002) based on Somusho Jigyosho Kigyo Tokei and Heisei 6 nen Jigyosho Meibo Seibi

* based on existing businesses in 1994. Survival rates are the proportion of companies in 1994 that had existed in 1991, change rates are proportion of companies whose business sector category changed between 1991 and 1994.

Table 4. Hamamatsu city expenditures on industry and commerce

	1969	1970	1971	1979	1980	1981	1988	1989	1990	1997	1998	1999
Industry and commerce	430	685	763	2242	2353	2363	3475	4436	6313	5337	8117	10977
Total city expenditure	27399	35404	40612	154742	169761	168778	253990	288232	361888	370387	374137	381594
as % of total expenditures	1.6%	1.9%	1.9%	1.4%	1.4%	1.4%	1.4%	1.5%	1.7%	1.4%	2.2%	2.9%
General spending	11749	14824	18423	83459	92663	90852	120276	133074	207934	182252	192913	195878
as% of general spending	3.7%	4.6%	4.1%	2.7%	2.5%	2.6%	2.9%	3.3%	3.0%	2.9%	4.2%	5.6%

Source: Hamamatsu Statistics various years

Table 5. Optoelectronics industry in Shizuoka

	1986	1991	2002
No. of companies in optoelectronics	71	66	61
No. of responding companies	40	66	61
Paid up capital less than 1 million dollars	62.5%	51.5%	62.1%
Employees less than 300	62.5%	52.3%	73.4%
Market entry into optoelectronics			
since 1980	59.5%	66.7%	86.7%
since 1985		25.4%	77.1%
since 1990			57.4%
since 1995			32.8%
Reason for entry in optoelectronics			
responding to demand	47.5%	54.5%	59.0%
higher value added	30.0%	42.4%	39.3%
new application of existing technology	25.0%	19.7%	41.0%
owning basic technology	22.5%	12.2%	23.0%
interest in optical technology	22.5%	15.2%	16.4%
demand from clients	17.5%	21.2%	24.6%
demand from parent company	12.5%	16.7%	24.6%
limitations in current business/products	10.0%	12.2%	14.8%
Share of optical business			
less than 20%	53.0%	73.6%	50.9%
between 20-80%	35.2%	13.2%	22.5%
more than 80%	11.8%	13.2%	26.6%
	100.0%	100.0%	100.0%
Expecting to expand optical business	70.6%		

Sources:
Shizuoka Commerce and Industry Section report (1986);
Hamanako International Intelligence Location Center report (1991)
Shizuoka Commerce and Industry Section report (2002)

Table 6. Optoelectronics industry in Shizuoka: changes in approaches and issues

	1986	1991	2
R&D approach			
working on its own	50.0%	30.0%	
working on its own and collaborating with research insts and univs.	26.2%	53.3%	
joint research with other companies, research insts, and univs	13.2%		
working on its own and contracting out to companies, research insts and univs	5.3%	8.3%	
others	5.3%	8.3%	
Total	100.0%	99.9%	
working on its own*			63.
joint research with other companies*			29.
joint research with univ and public research*			24.
joint research with parent and other companies*			23.
research contract with research insts. and universities*			4.
Key issues in R&D (multiple responses)			
Human resources development	97.5%	53.0%	39.
collaboration with external bodies	47.5%	42.4%	24.
technological information gathering	35.0%	48.5%	44.
identification of user needs	32.5%	62.1%	72.
planning and design	30.0%	24.2%	
organizational development and strengthening	15.0%	10.6%	
R&D budget*	10.0%	10.6%	24.
promoting joint research*			24.
contracting out research*			4.
Steps taken in HRD (multiple responses)			
attending seminars and conferences	46.1%	39.4%	
internal study groups	35.9%	24.2%	
sending to university and research institutes	23.1%	24.2%	14.
interacting with other companies	2.6%		13.
joint research with others*		34.8%	
Internal training*			49.
external recruits*			31.
sending staff to external raining*			23.
Technical information gathering			
specialized magazines/journals	92.5%	36.4%	50.
exhibitions	47.5%	33.3%	
parent companies	30.0%	12.1%	39.
patent	30.0%	22.7%	
seminars and conferences	27.5%	18.2%	
newspapers	27.5%	13.6%	
testing and research institutes	22.5%	10.6%	
universities	22.5%	12.1%	24.
clients/buyers	20.0%	15.2%	52.
suppliers/subcontractors	20.0%	10.6%	
other companies in different business areas	10.0%	9.1%	
other companies in similar business areas	10.0%	10.6%	
consultants	5.0%	3.0%	0.
private research institutes *			24.
public research institutes*			18.
clients and contractors*			52.
Main issues for product/business development			
lack of human resources	81.8%		60.
high costs owing to small batch production	18.2%		34.
inadequate sales routes	18.2%		
weak marketing	15.2%		
inadequate production	12.1%		11.
marketing and information collection*			67.
introduction of new technology and R&D*			65.
financing*			8.

Sources: Shizuoka Commerce and industry Section (1986); Hamanako International Intelligence Location Center (1991); Shizuoka Commerce and Industry Section (2002)

* multiple response items that were added in later surveys

Table 7 Patenting at HPK