Stellarator-Mirror FDS

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The FDS under study here (see Fig.1) consists of a stellarator with a small mirror part with lower magnetic field containing a two-ion component plasma [V.E.Moiseenko, K.Noack, O.Ågren "Stellarator-mirror based driven fusion-fission reactor" 35th EPS Conf. on Plasma Phys., ECA Vol.**32**, P-2.114 (2008)]. The goal of the mirror part in this proposed hybrid magnetic trap is to improve the hot ion confinement. If the mirror is non-axisymmetric and has a minimum B property, MHD stabilization is provided and considerable values of hot ion beta are achievable. Despite that the stellarator part does not confine efficiently hot ions, it confines well the background plasma, allowing for a higher electron temperature than can be provided by the open trap part solely. Neutral beam injection into the mirror part is one option to sustain the hot ions.

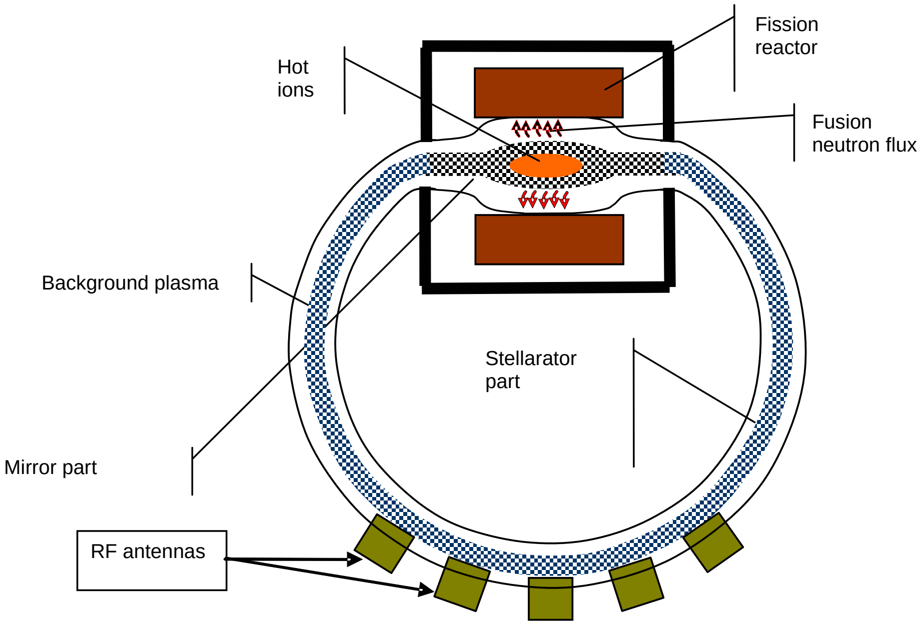

Fig. 1. Sketch of the stellarator- mirror FDS

Another option is ion cyclotron heating, which can be arranged by antennas located at the stellarator part far from the mirror region with the high neutron flux. The antenna field couples to the plasma, the waves propagate along the plasma column, reach the mirror part, propagate further to lower values of the magnetic field and becomes absorbed near the cyclotron resonances in the mirror part. The RF heating scheme could be arranged so, that the ion cyclotron resonance condition is met only at the mirror part.

Parameter	Proof-of-principle scenario	Reactor scenario
Stellarator beta	0.01	0.01
Mirror beta	0.15	0.15
Perpendicular tritium temperature	40 keV	150 keV
Background plasma temperature	400 eV	1.5 keV
Stellarator part magnetic field	2 T	5 T
Mirror ratio	1.5	1.5
Inverse aspect ratio	0.05	0.05
Plasma density	$1.2\cdot10^{14}\text{cm}^{-3}$	$2.1\cdot10^{14}\text{cm}^{-3}$
Minority concentration (in mirror part)	0.13	0.13
RF power	4.3 MW	37 MW
Fission power	28 MW	2.1 GW
Plasma minor radius	17 cm	32 cm
Torus major radius	3.4 m	6.4 m
Mirror length	2.1 m	4 m
Electric efficiency $Q_{el} = P_{el}^{out} / P_{el}^{RF}$	1.6	14

Table 1. Characteristics of two versions of FDS

To trap the hot ions at the mirror part, the perpendicular ion temperature should be higher than the parallel. This is provided by ion cyclotron heating which increases the perpendicular ion energy. Fusion neutrons are produced in the mirror region where the hot ions are confined. The mirror region is surrounded by a mantle of fission materials in which the fusion neutrons initiate fission of the nuclear fuel with a successive neutron multiplication. Calculation results for such a version of FDS are presented in Table 1.

Features

- The combination of a stellarator and mirror is beneficial to *localize the fusion neutron flux* to the mirror part of the device which is surrounded by a fission mantle. All equipment sensitive to neutron flux could be placed *outside the mirror part*.
- The device would be capable to *operate continuously*.
- It is expected that *full control on plasma* could be achieved: there would be no disruption or spontaneous instabilities which seriously influences the neutron production.
- The neutron production is tuneable and the *response time is short* which provides full control for power generation and reactor safety.
- *Two scenarios* could be realized in the machine: hot tritium in warm deuterium plasma and vice versa. Both scenarios are efficient with some advantage of the first.
- The calculations indicate promising potentials for the studied FDS scheme. In a broad range of machine parameters, a *high electric Q* is calculated.
- In a power plant scale the plasma part of the FDS machine is *compact* with a size comparable to existing fusion devices.
- An comparatively small experimental device could be built for a *proof-of-principle* demonstration which may even have a positive power output.
- Besides the commercial potential, construction and operation of the proposed FDS would contribute to the *development of fusion plasma* handling.