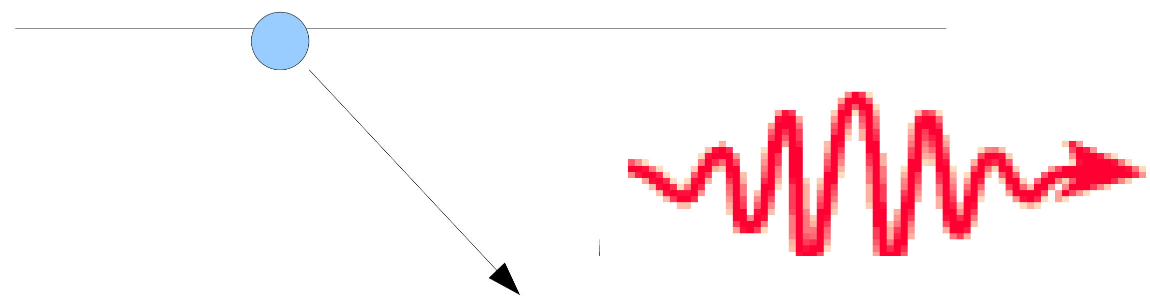
Optical Spectroscopy:

Hydrogen, Deuterium, and the Unidentified Mystery Tube



Rachel Bowens-Rubin

Outline

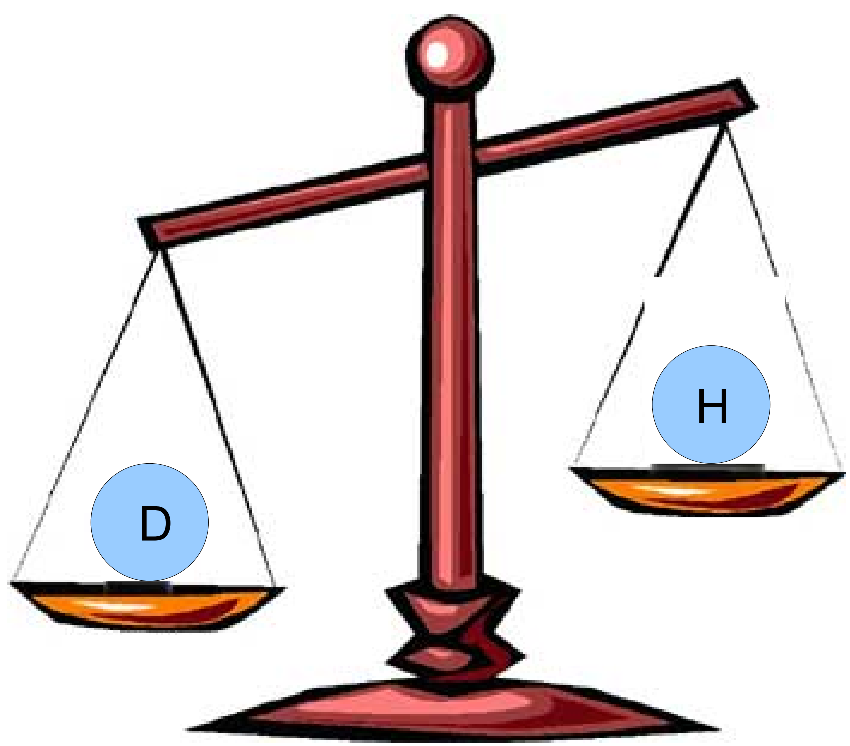
- Hydrogen and Deuterium Spectra
  - Purpose of Experiment
  - Theory: Rydberg Formula and Calculating Mass
  - Apparatus: Inside the Monochromator
  - Measuring H and D
  - Rh and Rd
  - Mass ratio
- Unknown lamp
  - What could it be?
  - Compare to other measures
  - Conclusions

Purpose: Hydrogen and Deuterium

1) Measure the Balmer lines of hydrogen and deuterium -- to find the shift

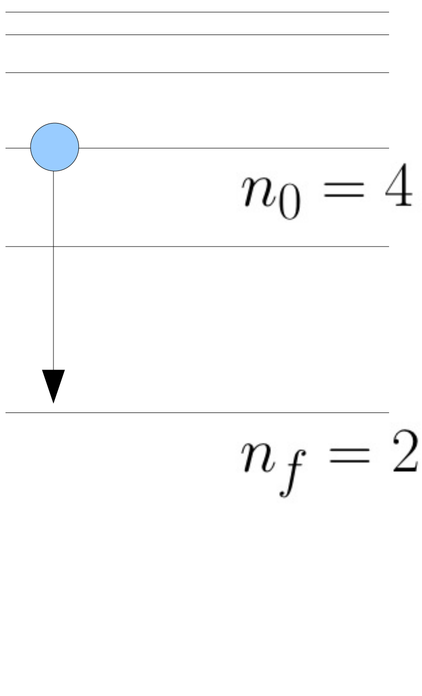
2) Calculate the Rydberg Constant

3) Determine the mass ratio the deuteron to the proton



Transitions Between Energy Levels

Rydberg Formula



$$\frac{1}{\lambda} = \mu R_\infty \left(\frac{1}{1/n_f^2 - 1/n_0^2}\right)$$

$\lambda =$ wavelength

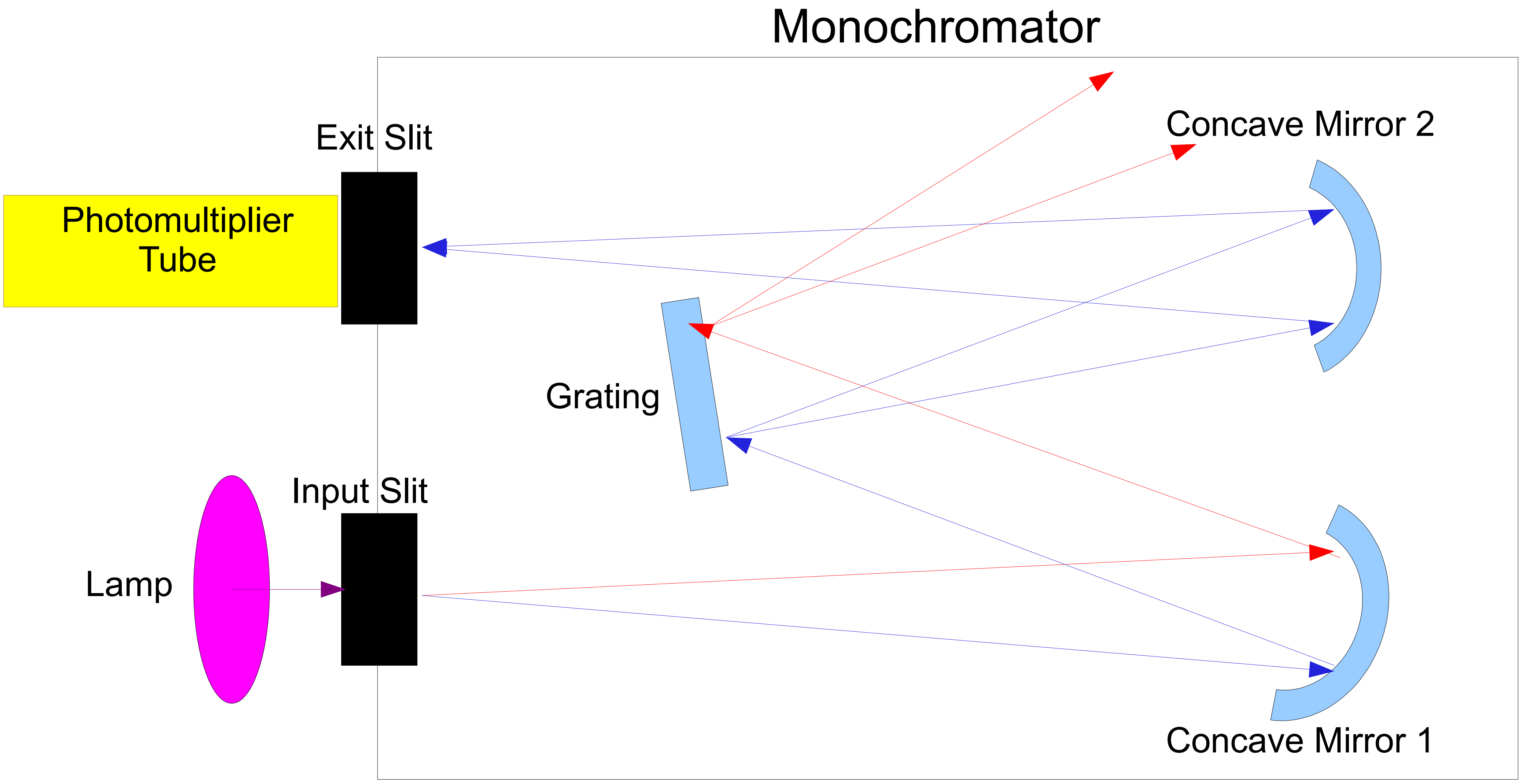
$\mu =$ reduced mass $= \frac{M_{nucleus}}{M_{nucleus} + M_{electrons}}$

$R_\infty =$ Rydberg constant $= 1.0973731569 * 10^7 m^{-1}$

$n_0 =$ initial energy states

$n_f =$ final energy states of the electron

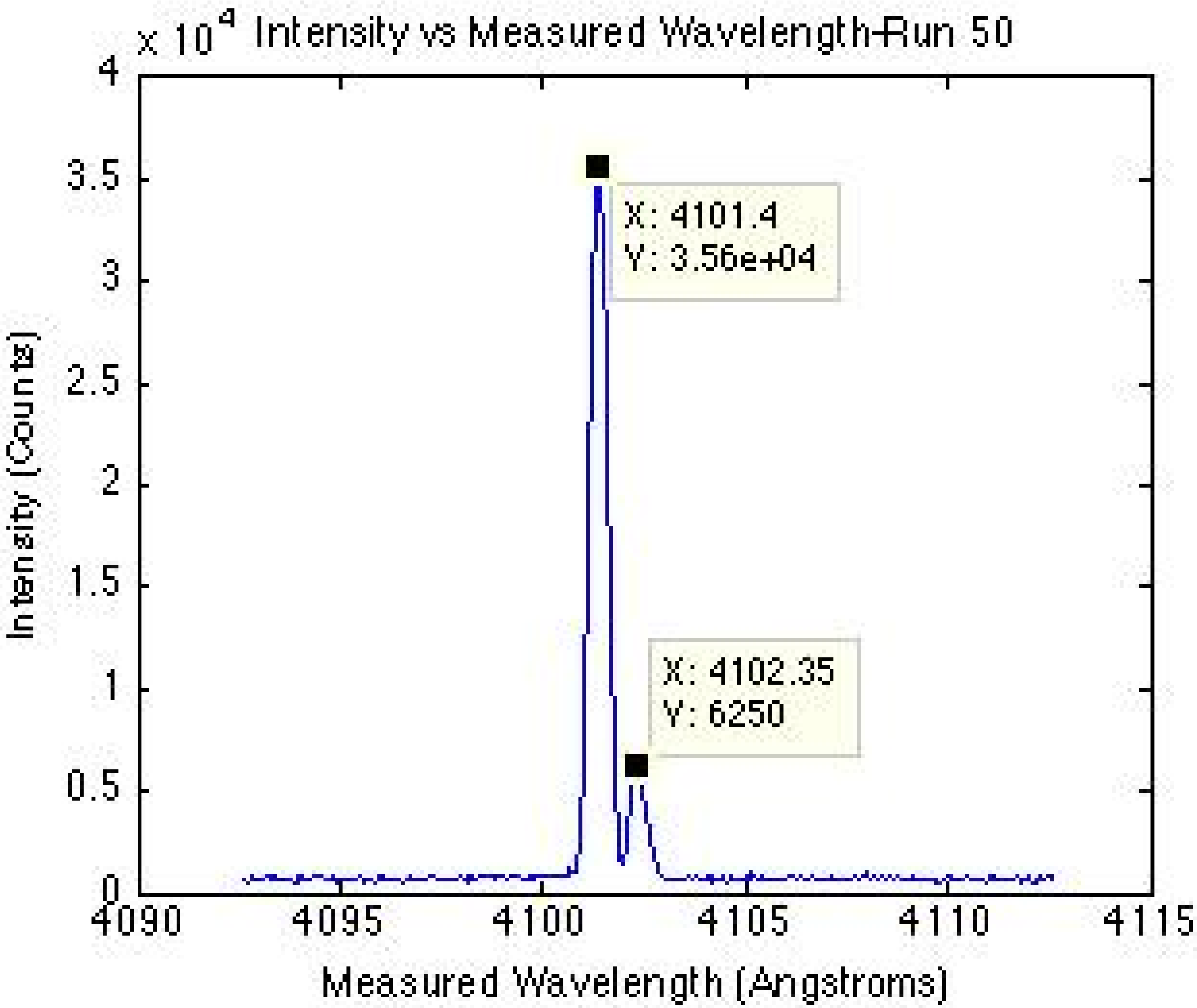
Inside the Monochromator



Grating Disperses Light following the Grating Equation:

$$n\lambda = a\left(\sin i - \sin\theta\right)$$

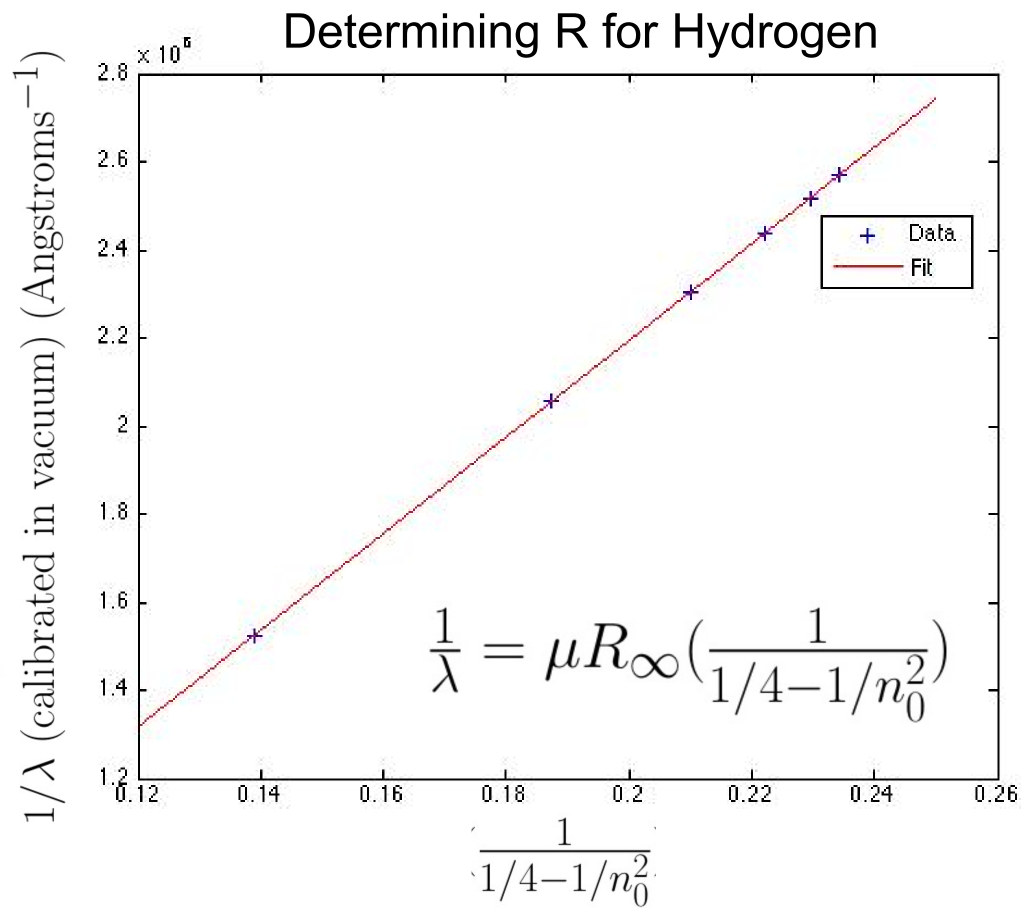
Data Collection

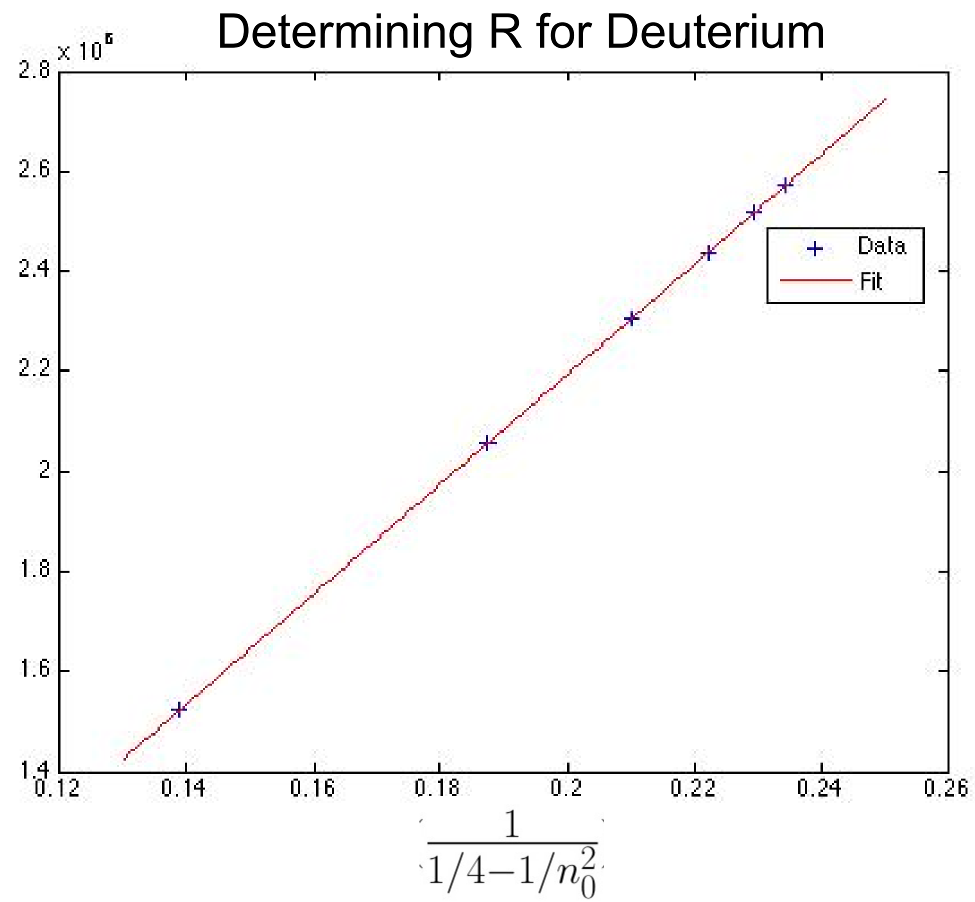


- Measured 6 Balmer Lines
- Calibrated using Hg fit
  - Air → Vacuum
  - Error on each point is dominated by the fit = 1.97 A

Example Data Set: Delta line of D
•Peak on right from H in the tube

Results for Rydberg Constants





$$R_h = \mu_h R_\infty = 1.0959 * 10^7 \pm 0.00020 * 10^7 m^{-1}$$

$$R_d = \mu_d R_\infty = 1.0970 * 10^7 \pm 0.00026 * 10^7 m^{-1}$$

Mass Ratio

$$M_d = \frac{M_e \lambda_H}{M_e \lambda_H - \Delta\lambda - \Delta\lambda M_e}$$

M_d = mass of a deuteron

M_e = mass of an electron

λ_H = measured hydrogen line

λ_D = measured deuterium line

$\Delta\lambda = \lambda_H - \lambda_D$

$$\frac{M_d}{M_p} = 2.3508 \pm 0.4495$$

- Assumed mass proton = 1amu
- Measured mass ratio within one std of expected ratio = 2

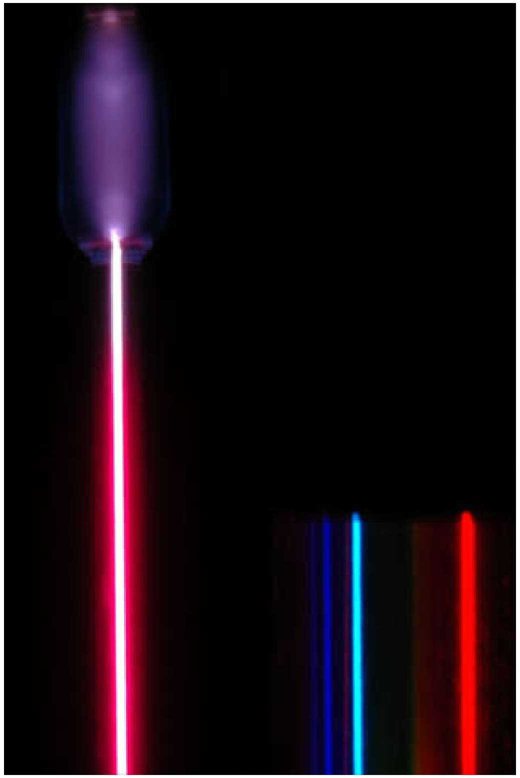
Summary

	Measured λ	Expected
R_h	$1.0959 * 10^7 \pm 0.00020 * 10^7 m^{-1}$	$1.0967 * 10^7 m^{-1}$
R_d	$1.0970 * 10^7 \pm 0.00026 * 10^7 m^{-1}$	$1.0971 * 10^7 m^{-1}$
M_d/M_p	2.35 ± 0.45	2.00

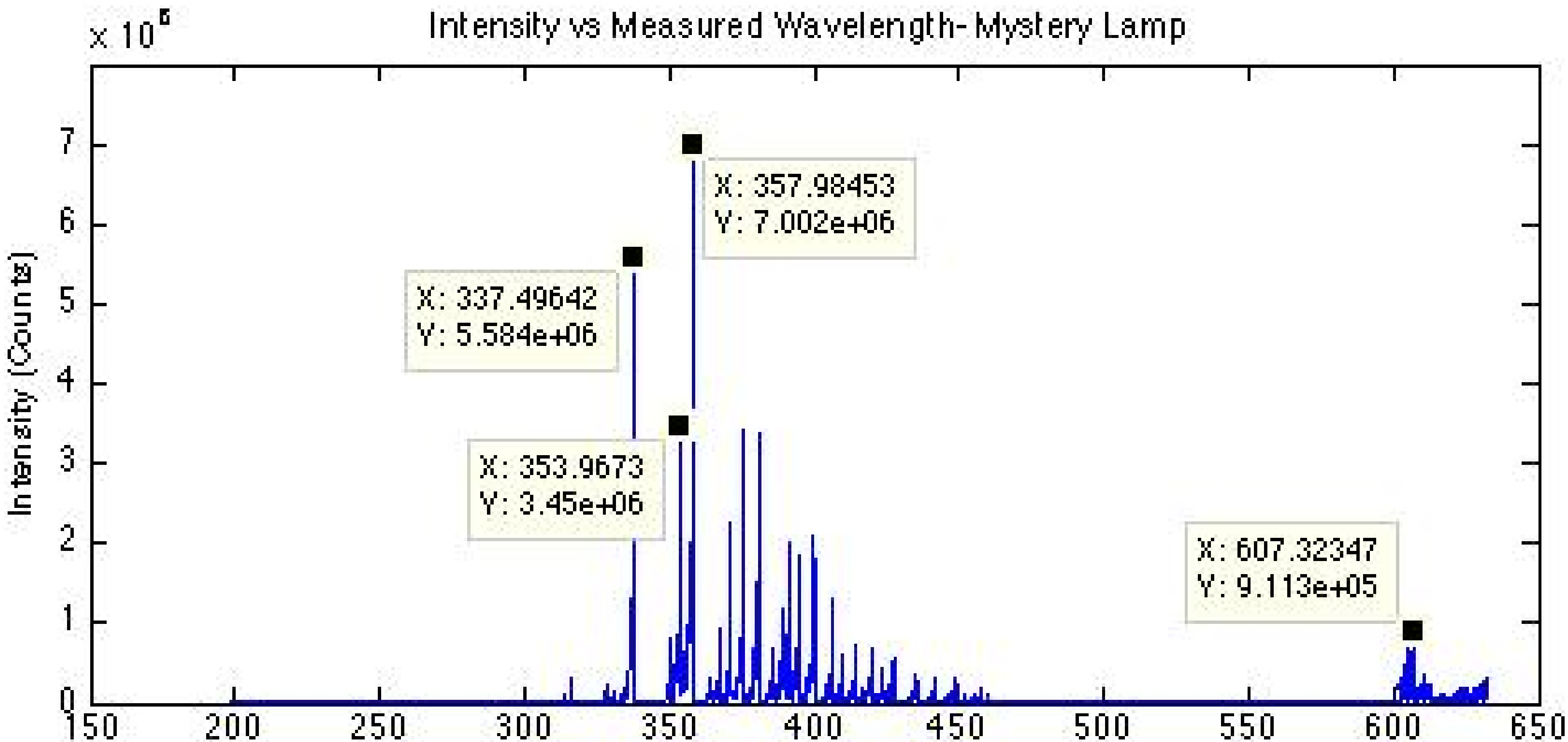
- Rh, Rd, and the mass ratio were within one std of the expected
- Error from fit > Measurement Error

What is in the Mystery Lamp?

- Narrowing the options:
  - Only experiment in back room using tubes
  - Oriel makes 5 Calibration tubes: Ar, Kr, Ne, Xe, Hg/Ne
  - Color slightly redder than H and D
  - Investigated some other options
- Compared to lines listed in:
  - Oriel Catalog
  - CRC Handbook for Chemistry and Physics

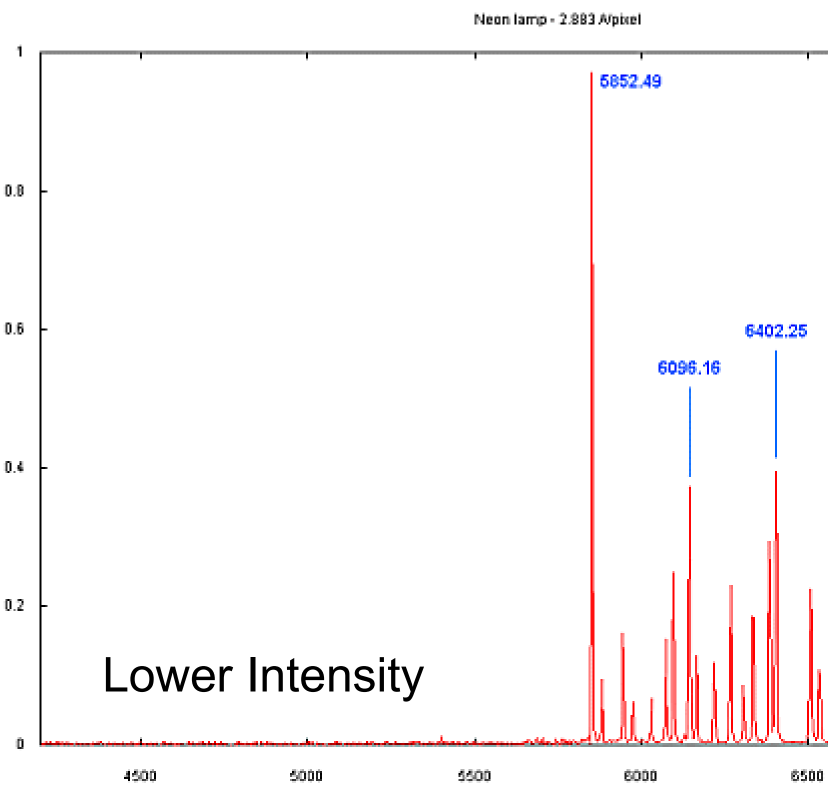


Hydrogen Tube

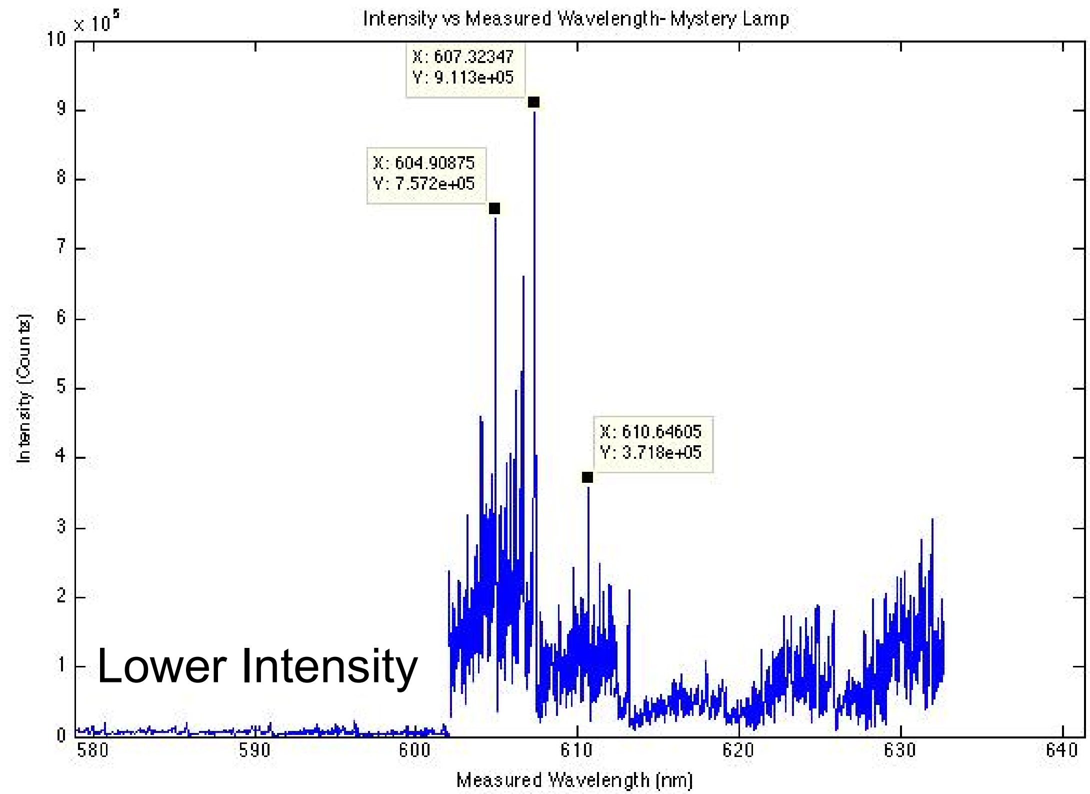


Measured λ (nm)	CRC (nm)	Oriel (nm)
337.5 ± 0.2	337.8	337.0
354.0 ± 0.2	354.2	352.1
358.0 ± 0.2	357.4	359.4
607.3 ± 0.2	607.4	607.4

Compare to Other Measures: 450 to 630nm

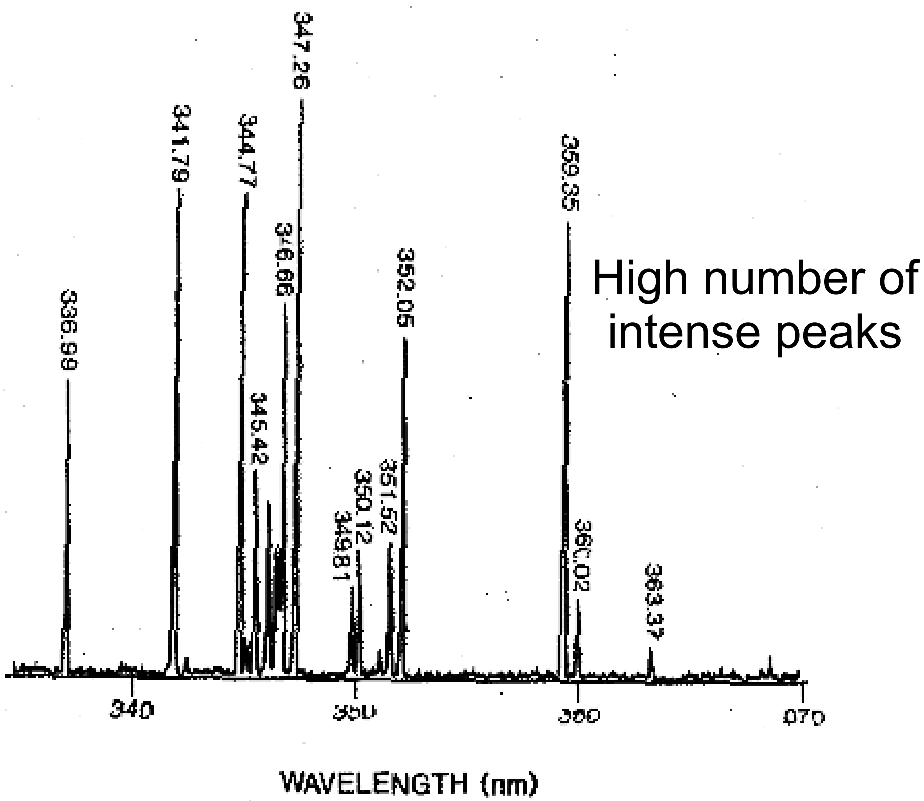


Published Neon Tube
Spectrum data
(Astrosurf)

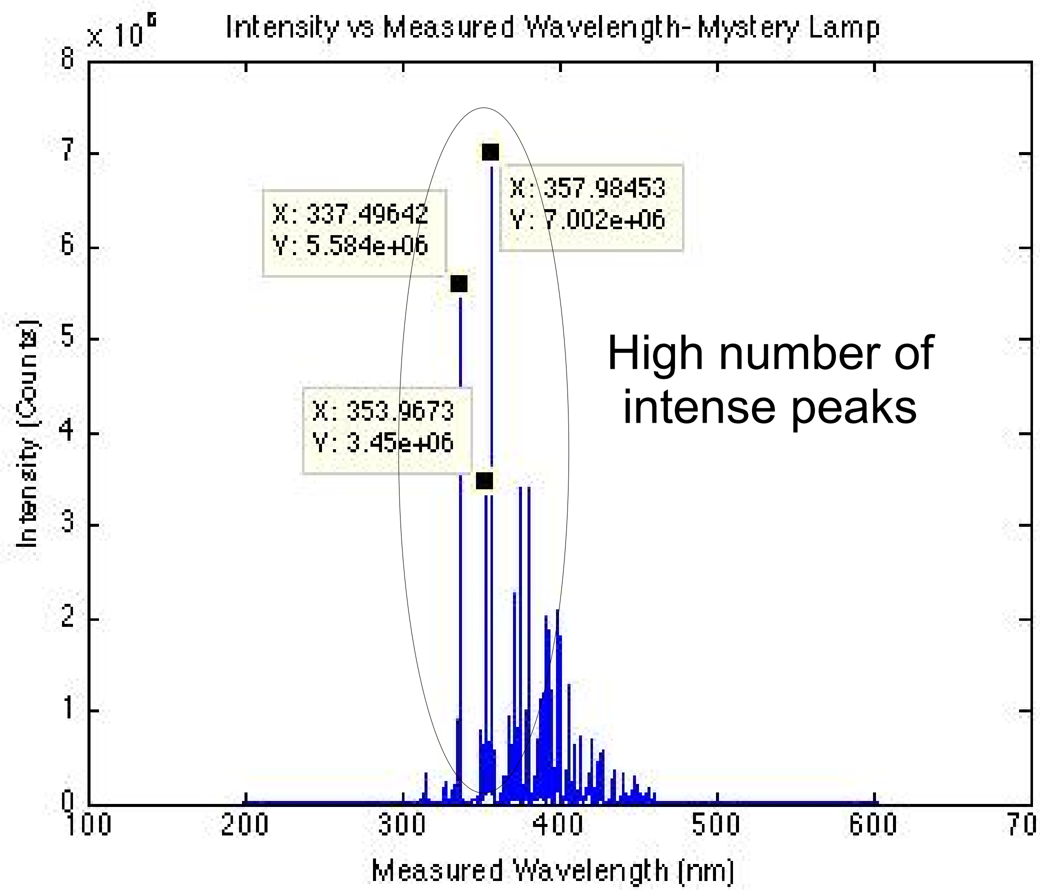


8.13 Mystery Tube

Compare to Other Measures: 330 to 360nm



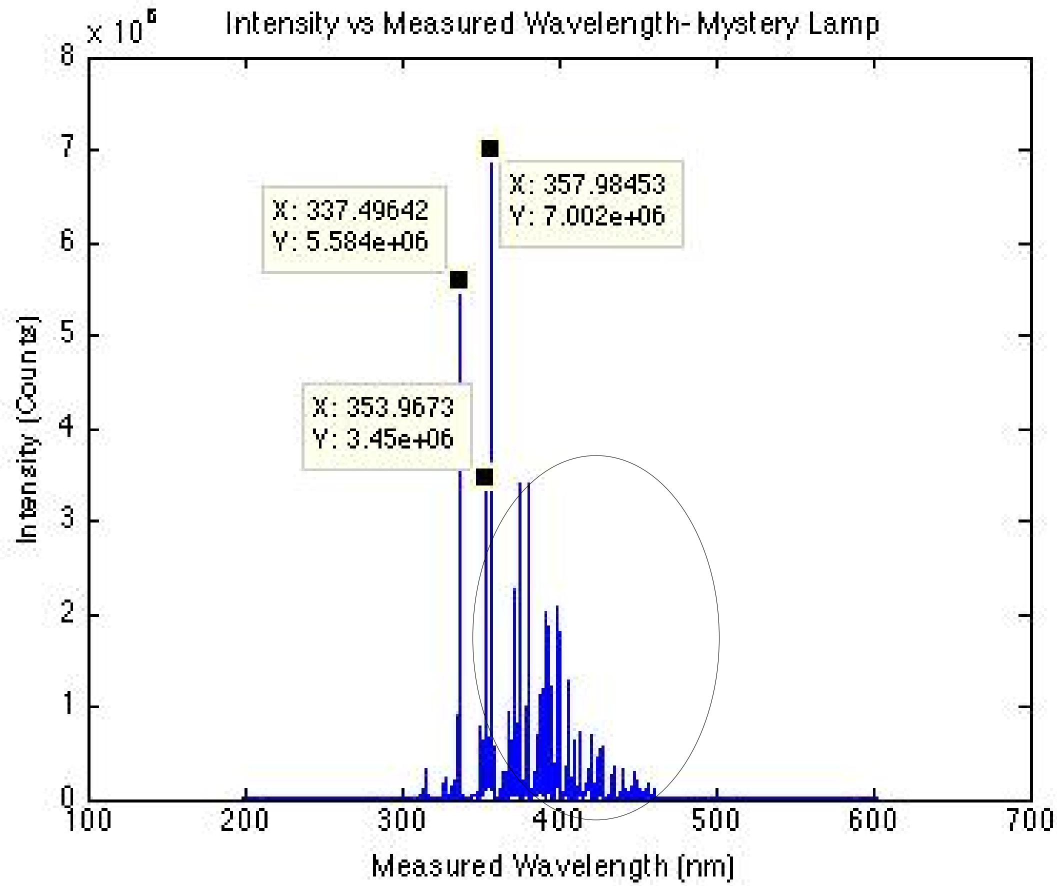
Typical Spectra of Oriel Spectral Calibration Lamps: Ne



8.13 Mystery Tube

Unexplained Region

- 375nm to 450nm
- The 5 Oriel calibration lamps do not have peaks in this region
- Probably another element



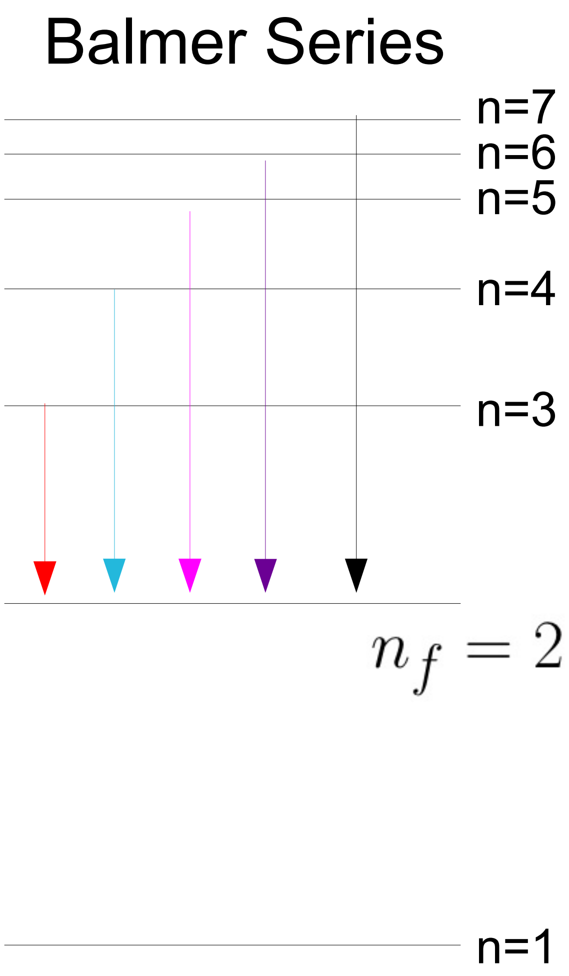
Conclusions

- Neon
  - Main Peaks match
  - Similar Overall Shape
- Plus another element
- More data should be taken to confirm

References

- CRC: Handbook for Chemistry and Physics
- Melissionos, *Experiments in Modern Physics*. Academic Press, 1966.
- French and Taylor. *An Introduction to Quantum Physics* (Norton, 1978).
- MIT Physics Department, Junior lab written report notes (2007).
- Georgia State University. Hyperphysics http://hyperphysics.phyastr.gsu.edu/hbase/quan

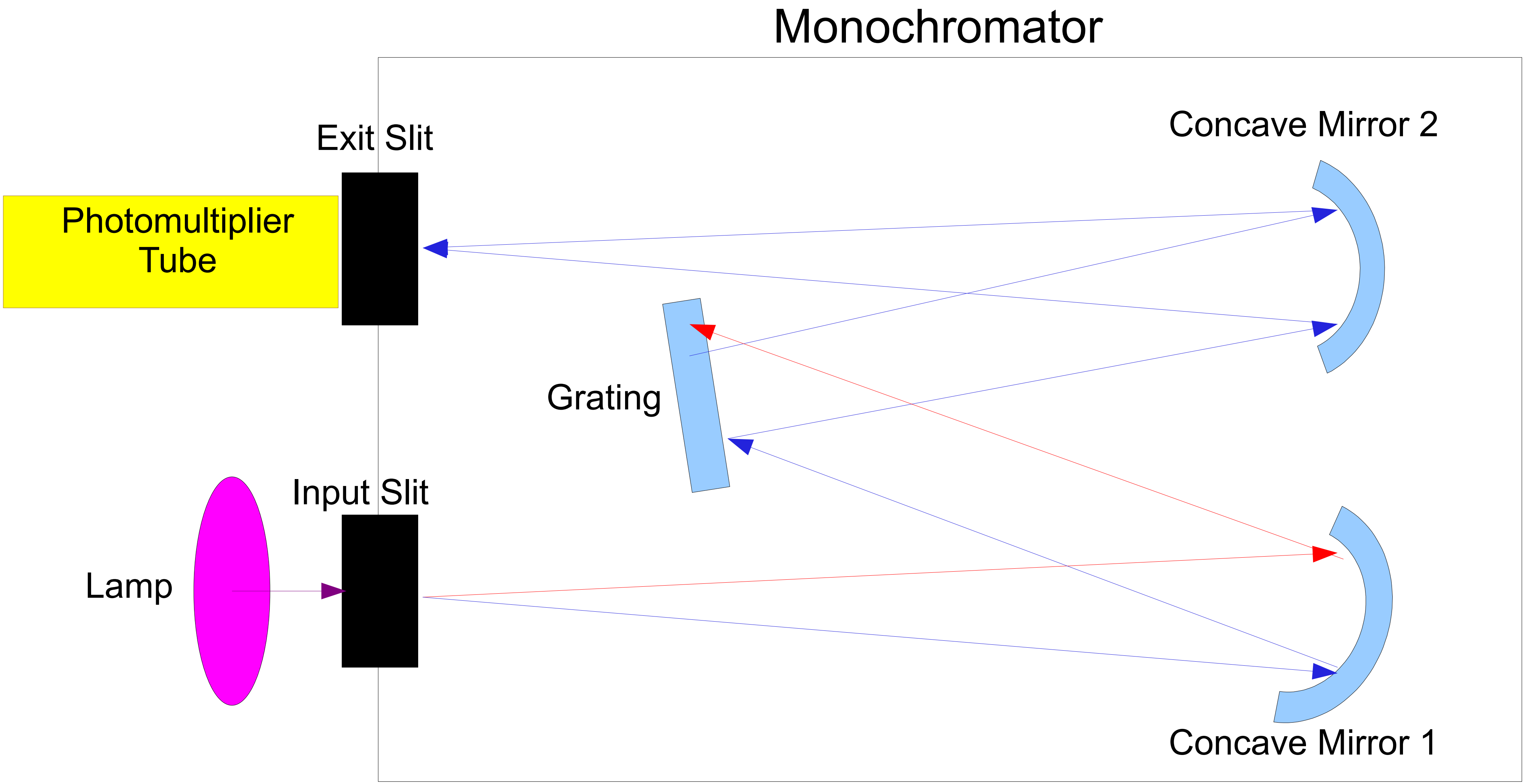
Balmer Series



Nitrogen Lines

Intensity	Wavelength/Å	
360	3919.00	II
90	3938.52	III
450	3955.85	II
1000	3995.00	II
150	3998.63	III
200	4003.58	III
360	4035.08	II
550	4041.31	II
360	4043.53	II
150	4057.76	IV
250	4097.33	III
140	4099.94	I
200	4103.43	III
185	4109.95	I
285	4176.16	II
120	4195.76	III
150	4200.10	III
285	4227.74	II
285	4236.91	II
220	4237.05	II
450	4241.78	II
90	4332.91	III
120	4345.68	III
300	4379.11	III
285	4432.74	II
650	4447.03	II
90	4510.91	III
120	4514.86	III
360	4530.41	II
550	4601.48	II

Inside the Monochromator



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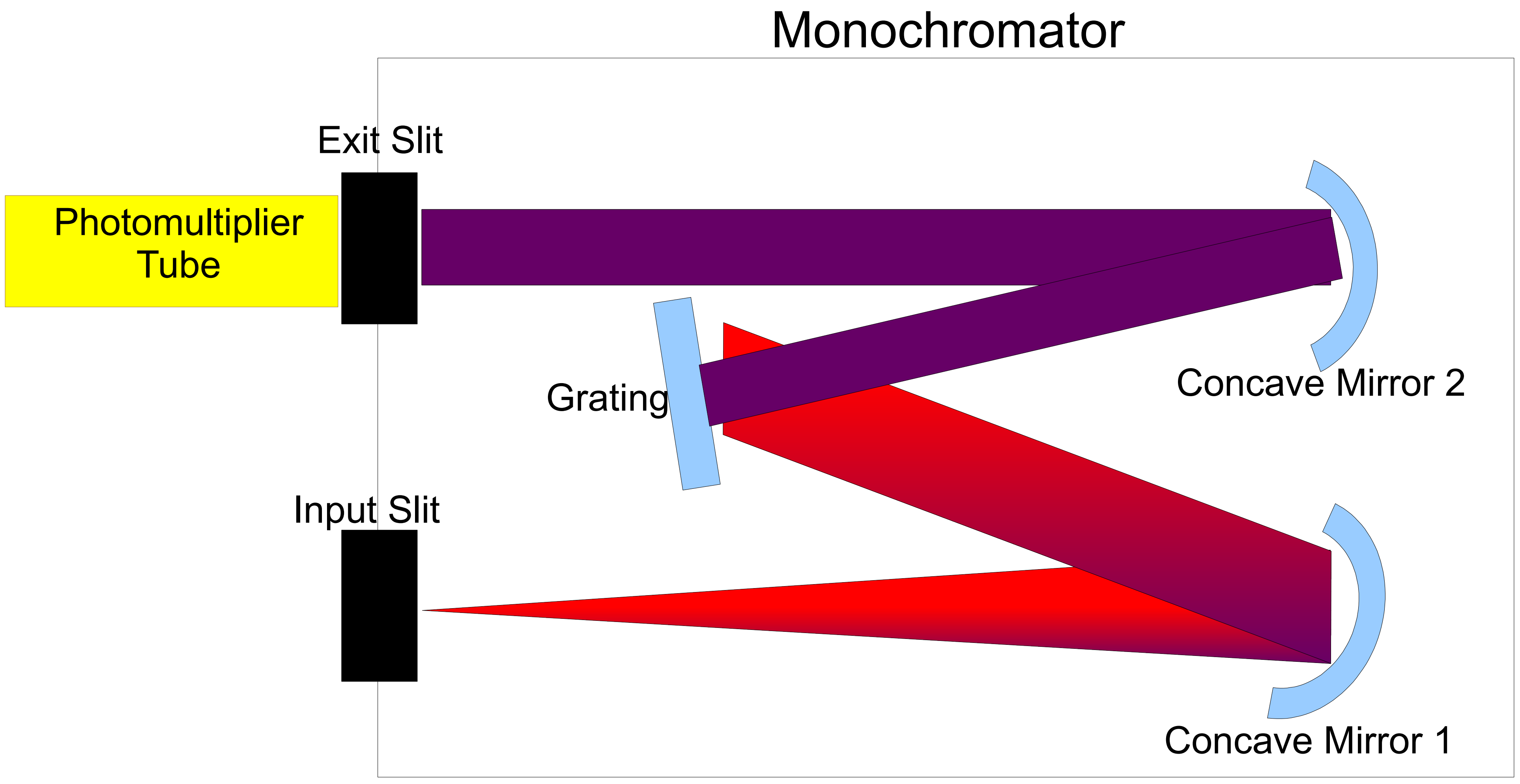

Monochromator
Exit Slit
Photomultiplier Tube
Grating
Concave Mirror 2
Input Slit
Concave Mirror 1

Mass of a Deuteron

$$M_d = \frac{M_e \lambda_H}{M_e \lambda_H - \Delta\lambda - \Delta\lambda M_e}$$

$M_d = \text{mass of a deuteron}$

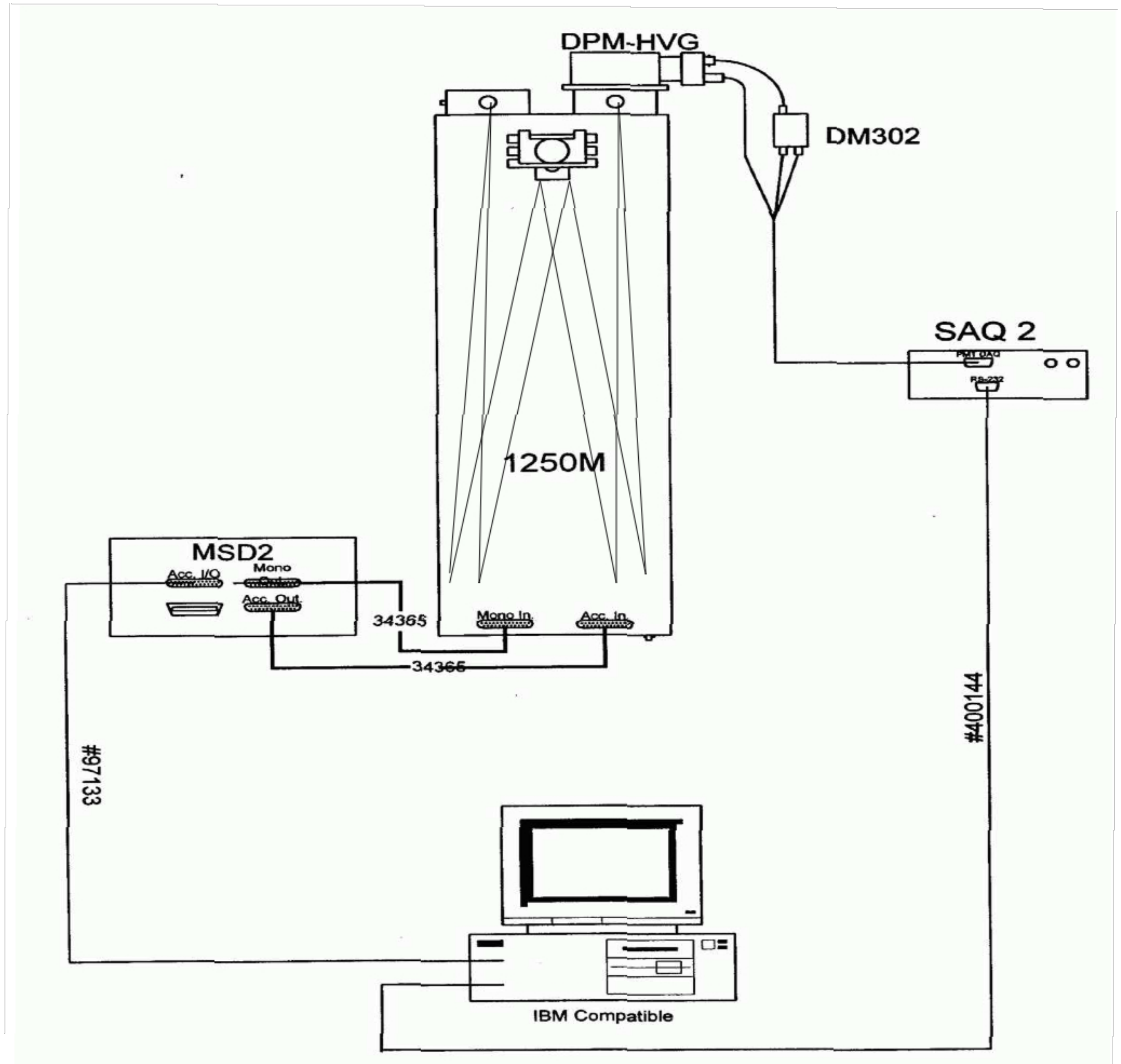
$M_e = \text{mass of an electron}$

$\lambda_H = \text{measured hydrogen line}$

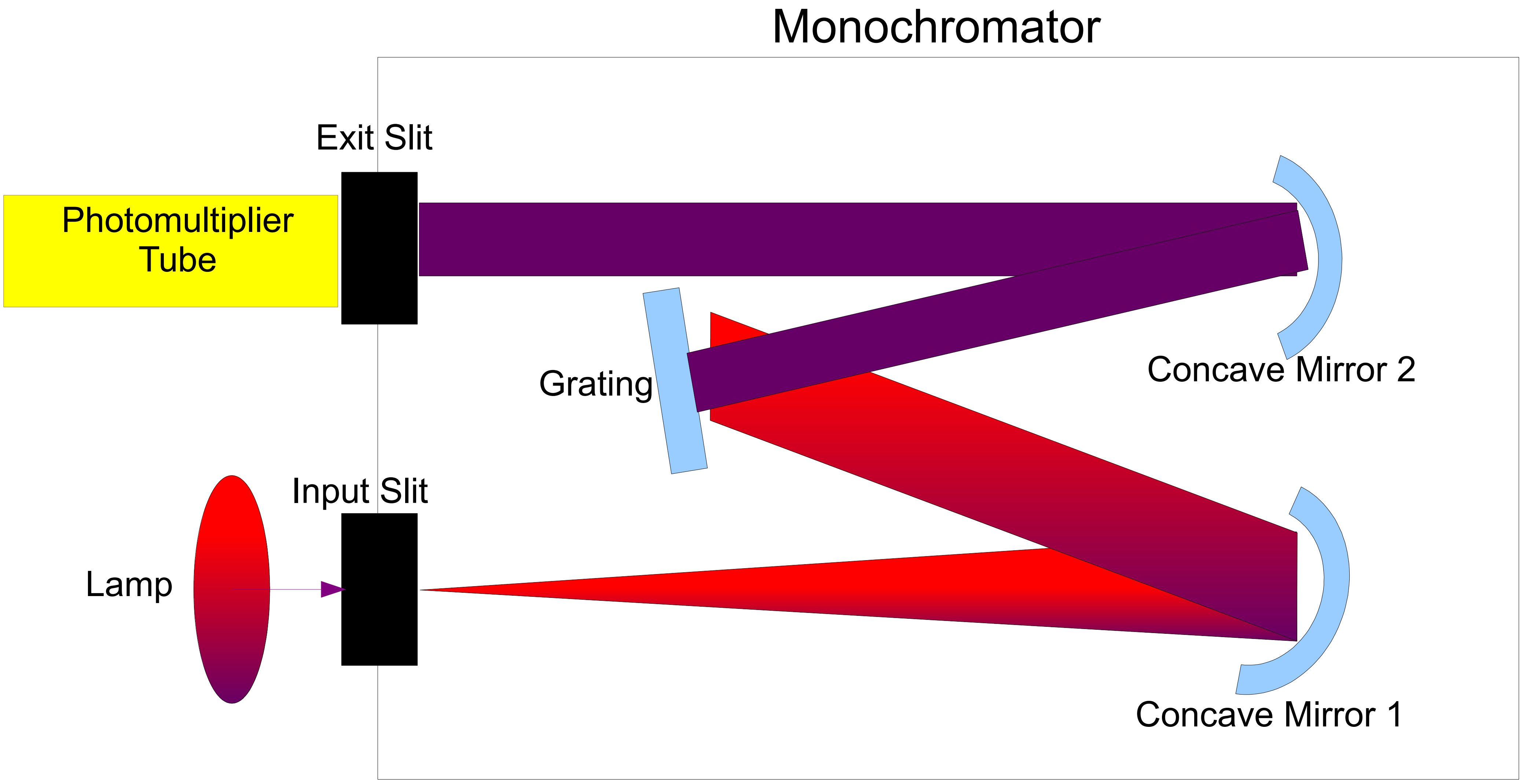
$\lambda_D = \text{measured deuterium line}$

$\Delta\lambda = \lambda_H - \lambda_D$

Apparatus


DPM-HVG
DM302
SAQ 2
RS-232
1250M
MSD2
Acc. I/O
Mono
Acc. Out
34365
Mono In
Acc. In
34365
#400144
#97133
IBM Compatible

Inside the Monochromator



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$$n\lambda = a\left(\sin i - \sin\theta\right)$$