UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
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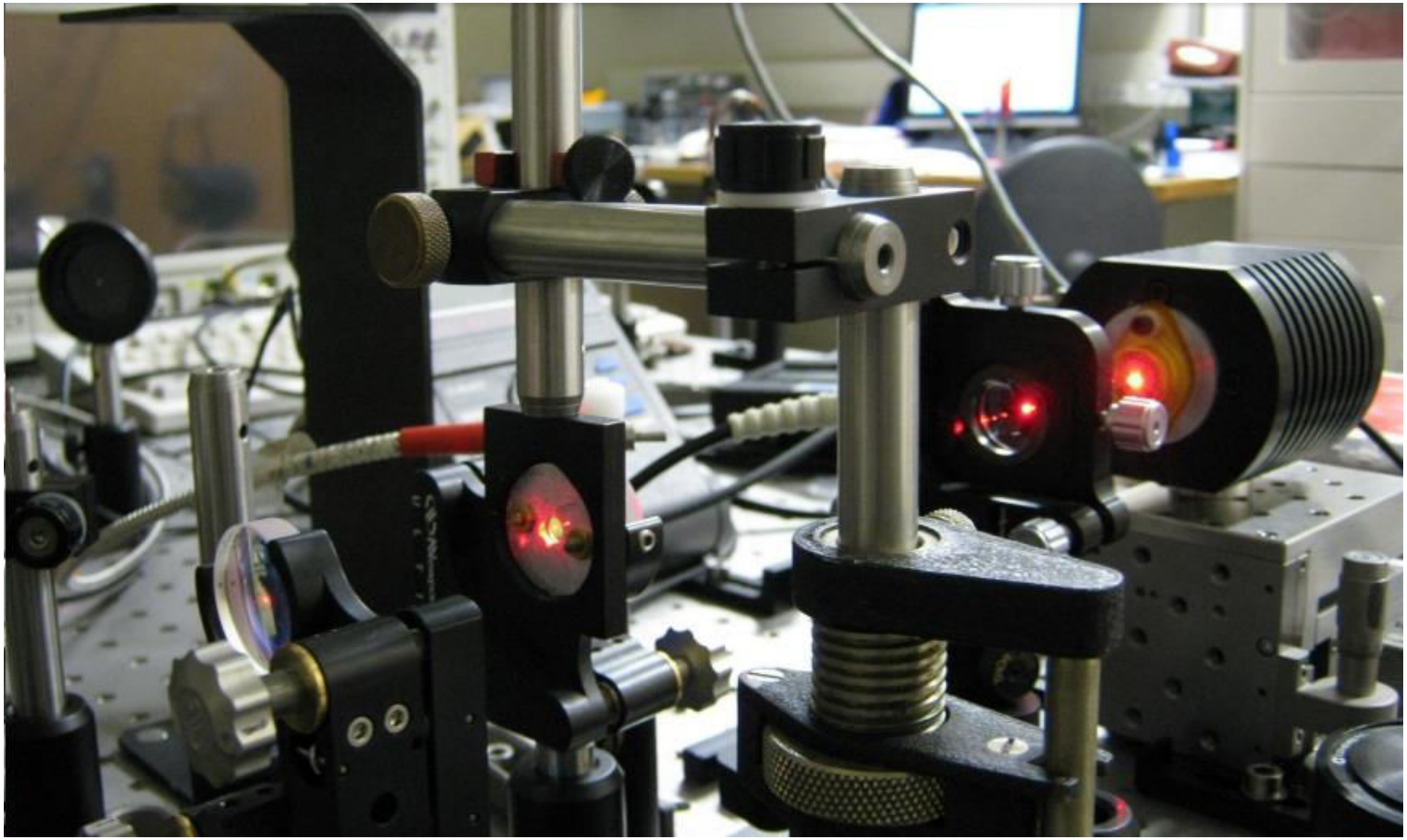
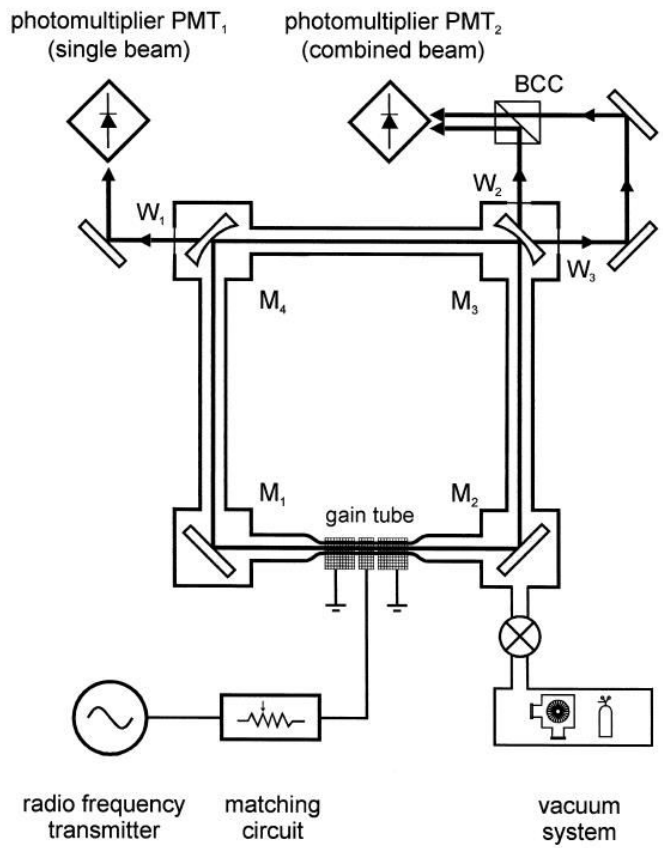
Rotation Sensing with Lasers

Jon-Paul Wells, Ulrich Schreiber (and many others)
Department of Physics & Astronomy



Bi-Directional Ring Lasers



Sensitivity to (for example) Earth rotation, described by the instantaneous angular velocity vector Ω, is given by the Sagnac frequency, which can be observed as the frequency difference between two counter rotating laser beams:

$$\Delta f = \frac{4A}{\lambda P}\vec{n}\cdot\vec{\Omega}$$

with

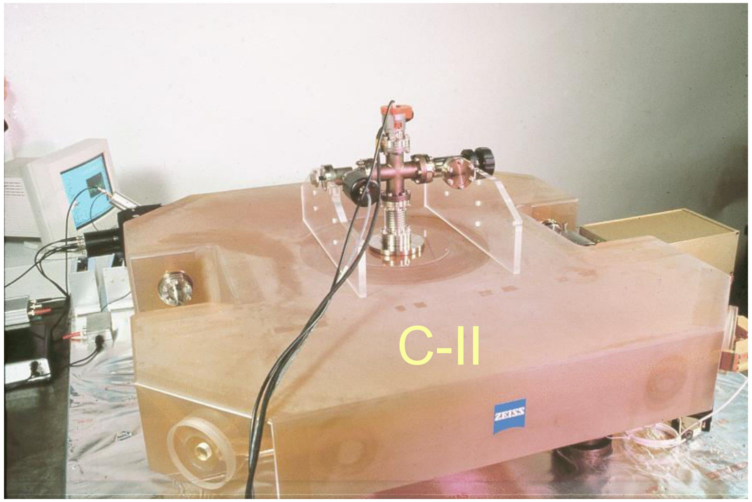
A area enclosed by the laser beam

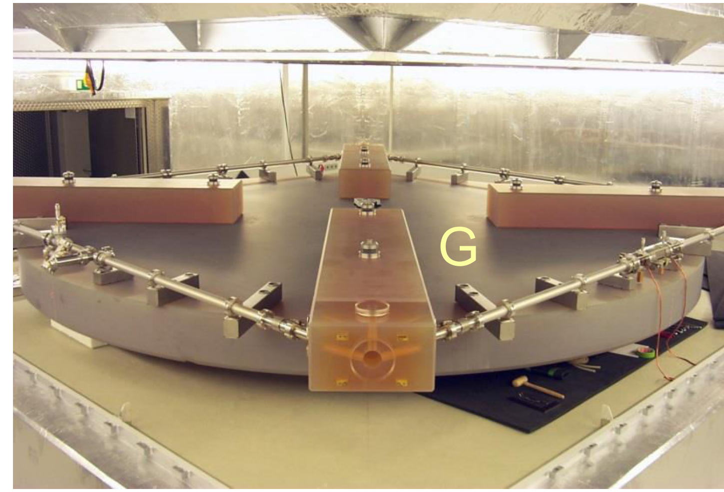
n normal vector of A

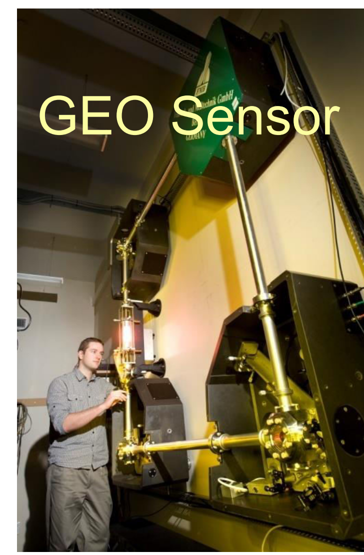
P perimeter

λ optical wavelength

Bi-Directional Ring Lasers



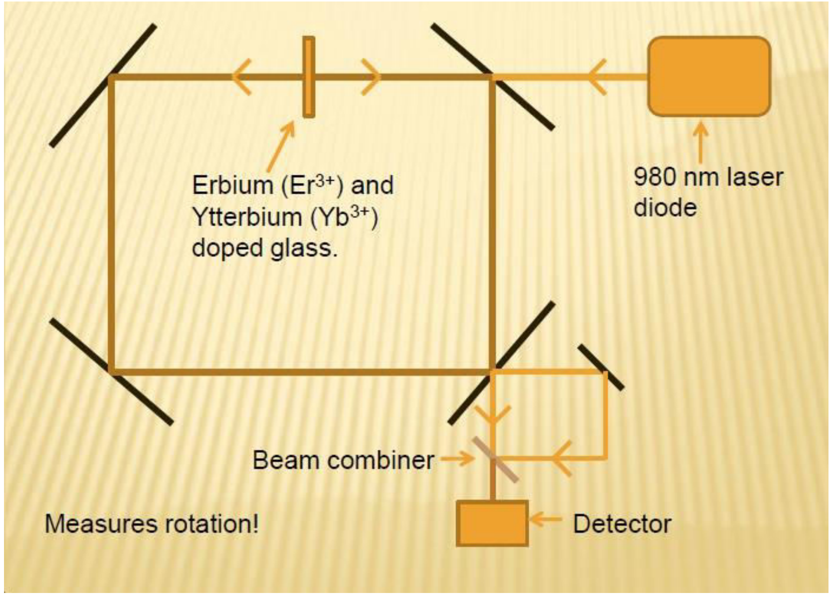


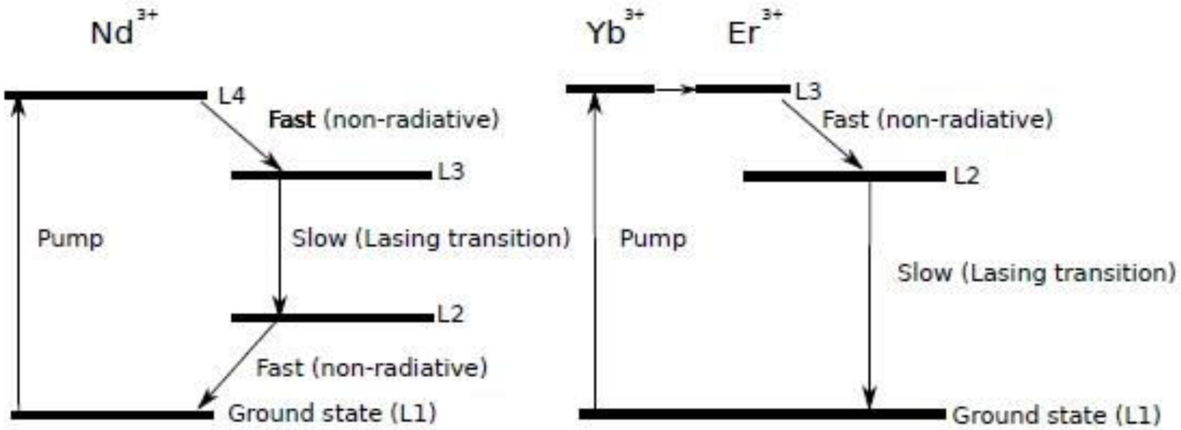


Six orders of magnitude increase in sensitivity in 25 years

Different Concept: All Solid State Sensors

- Replace the gain medium for a high gain, condensed phase alternative.
- We have used phosphate glass doped with (optically active) lanthanide ions.

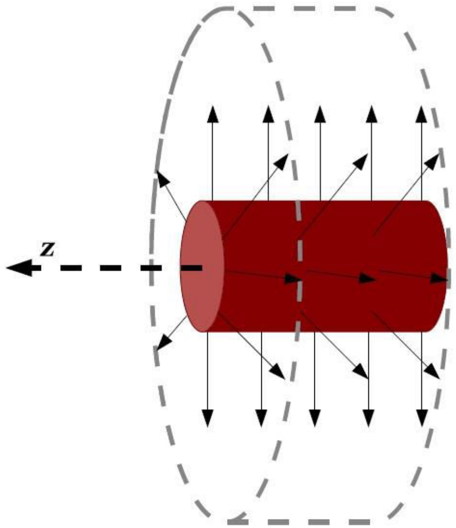


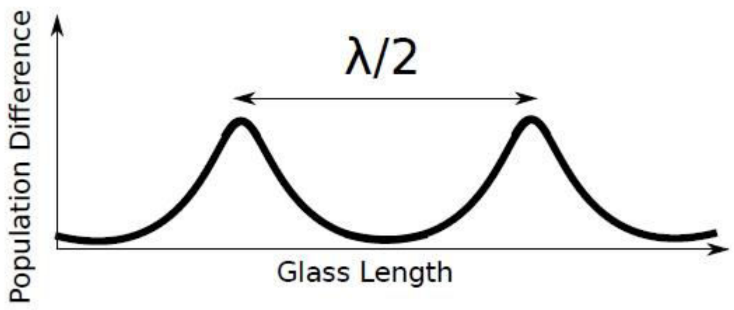


Different Concept: The Hitch…

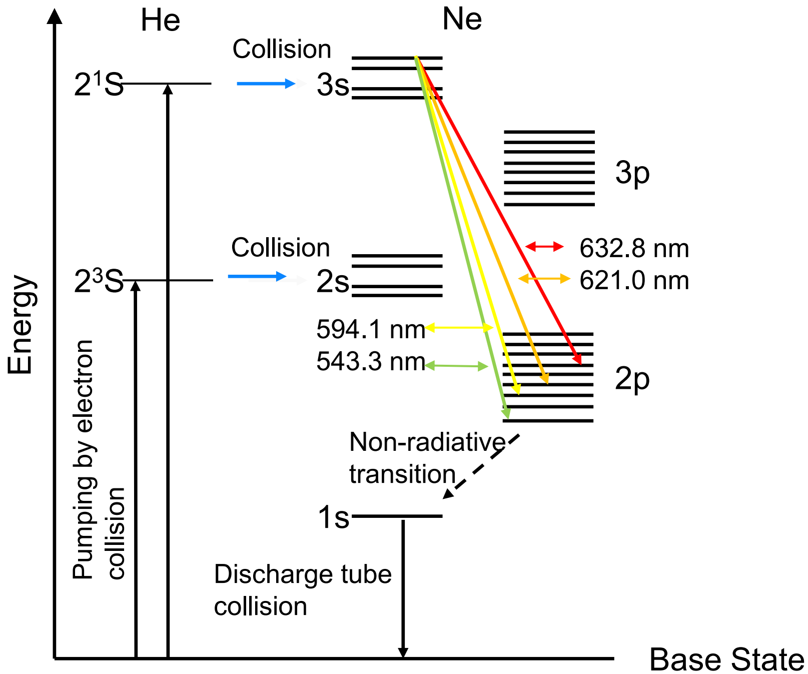
- In a static, solid state material the counter propagating travelling waves induce a gain grating.

- From this both beams can strongly interact, leading to intensity oscillation or even uni-directional lasing

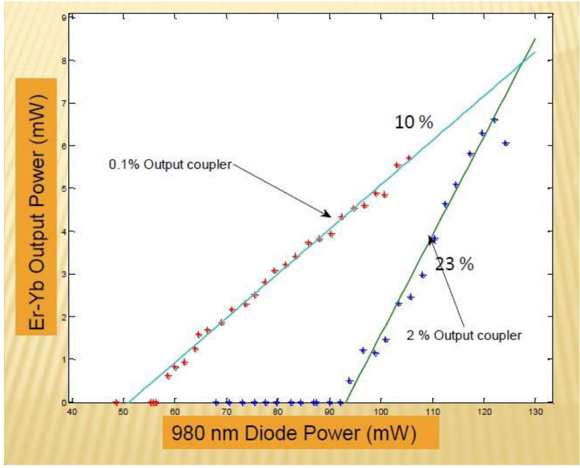


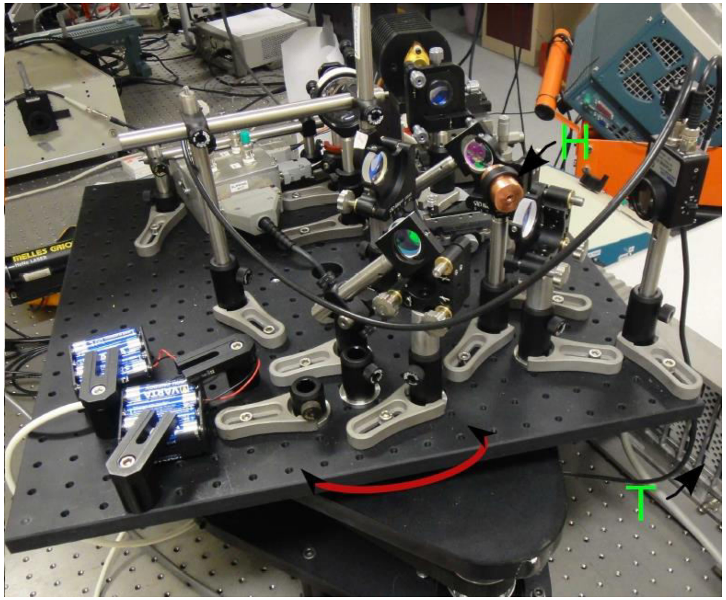


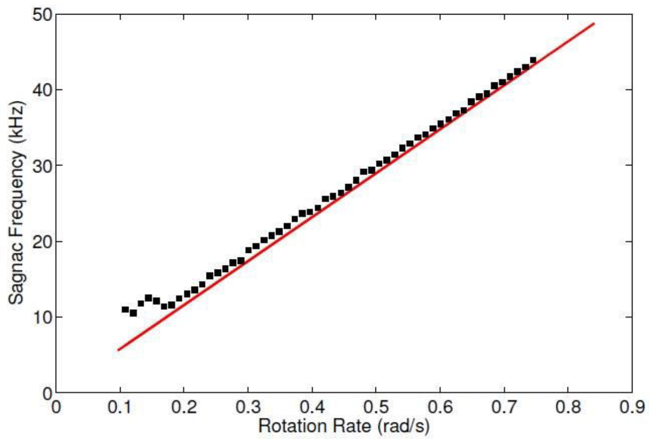
Contrast with Helium-Neon



Free Space Ring.

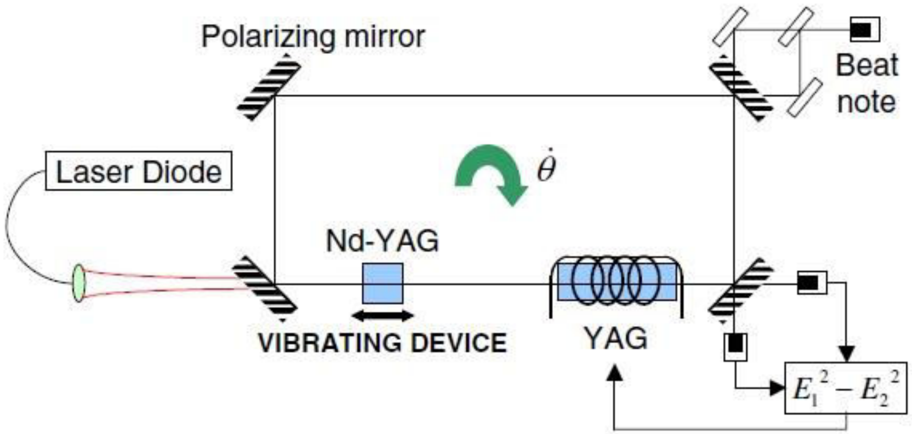


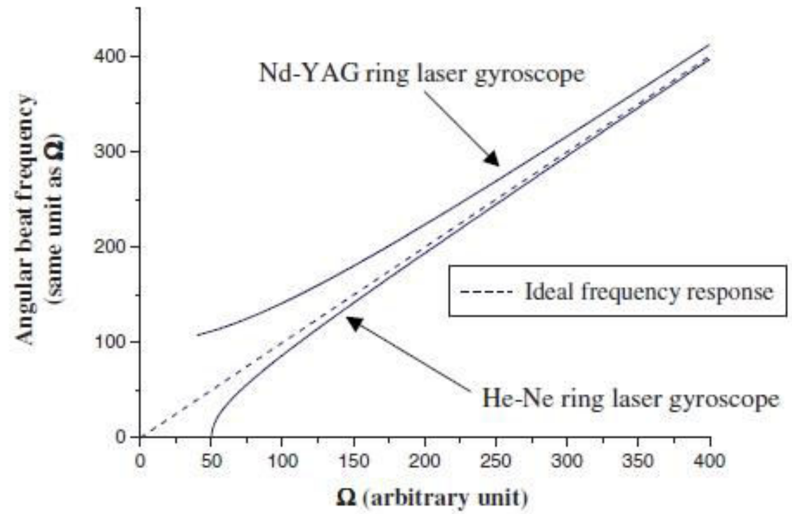




- Phosphate glass: Er/Yb
- Laser wavelength 1.53 micron
- Lasing threshold 50 mW.

Earlier Work used YAG:Nd





Mode-Coupling Control in Resonant Devices: Application to Solid-State Ring Lasers

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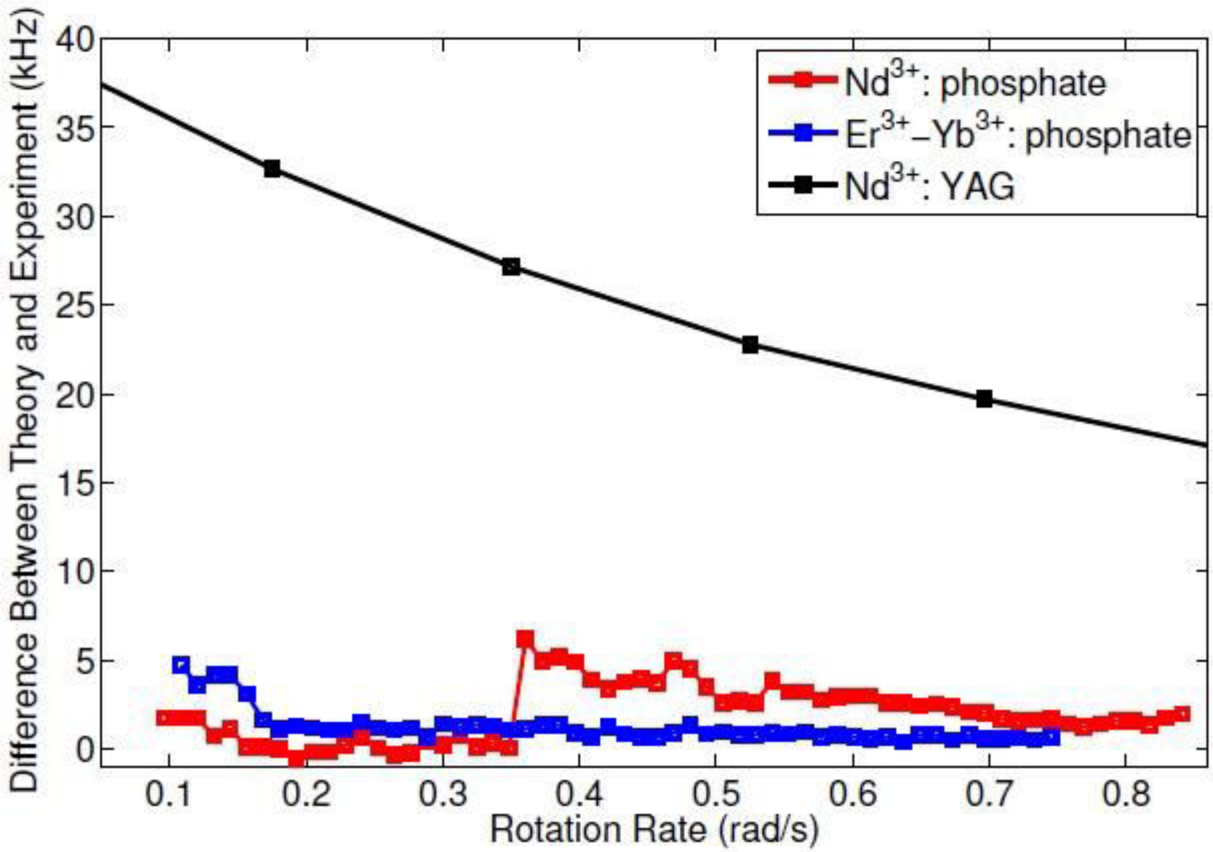
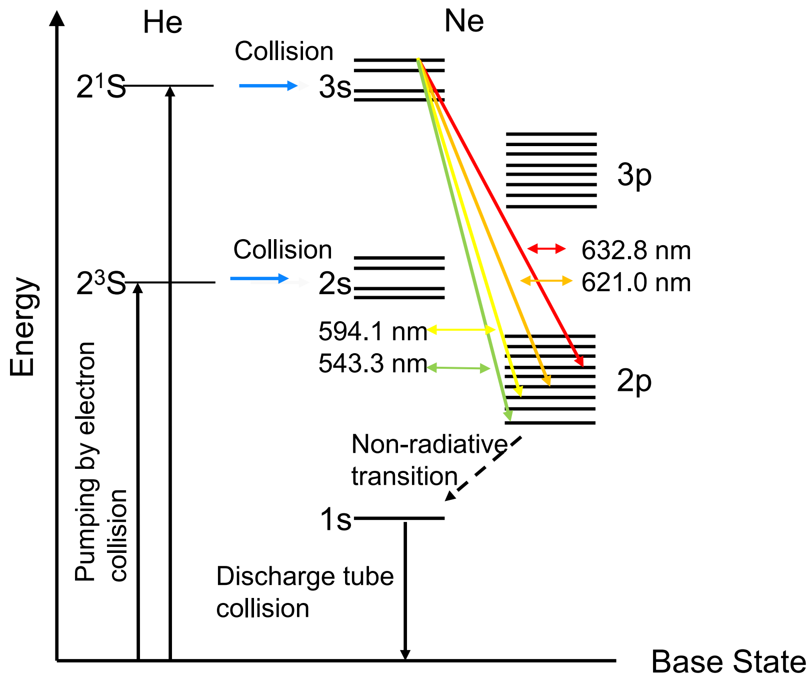
Comparison: YAG vs Phosphate Glass



Return to the Helium-Neon system

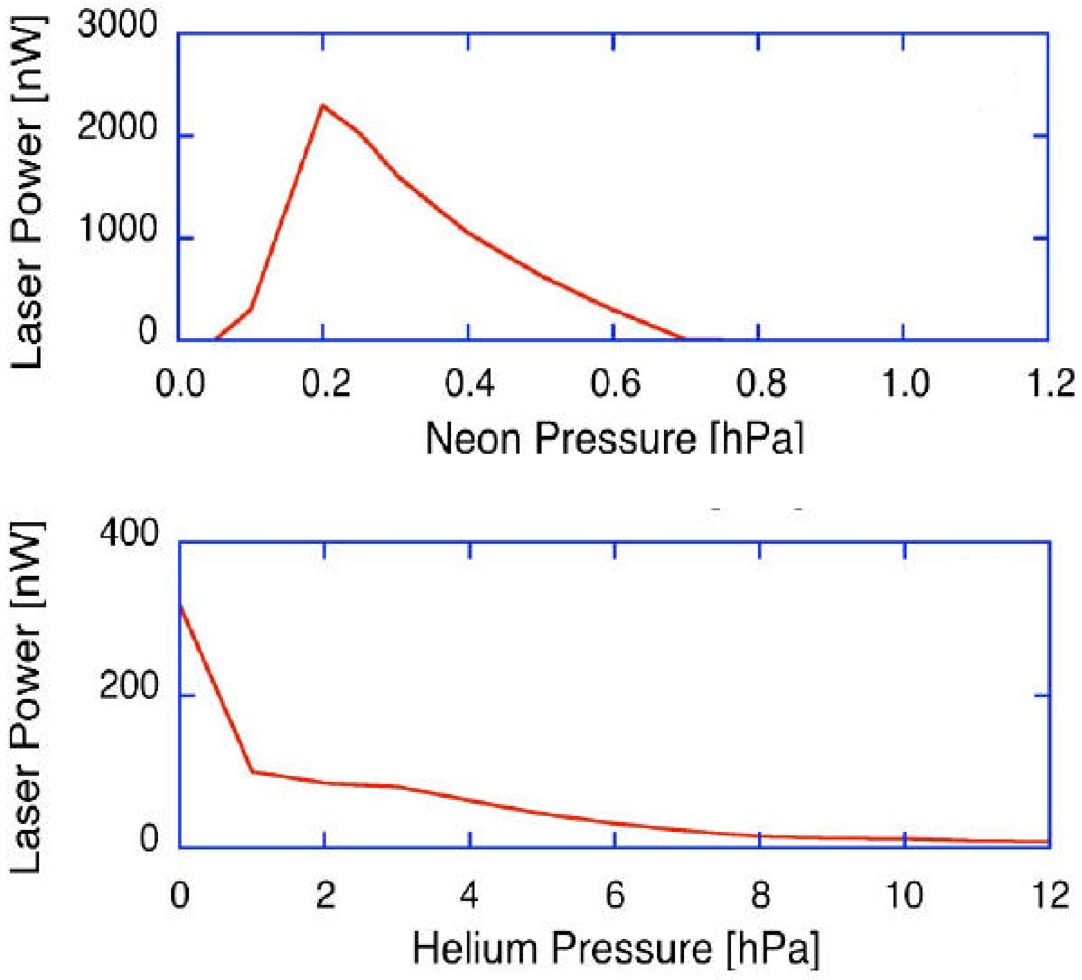


$$\Delta f = \frac{4A}{\lambda P}\vec{n}\cdot\vec{\Omega}$$

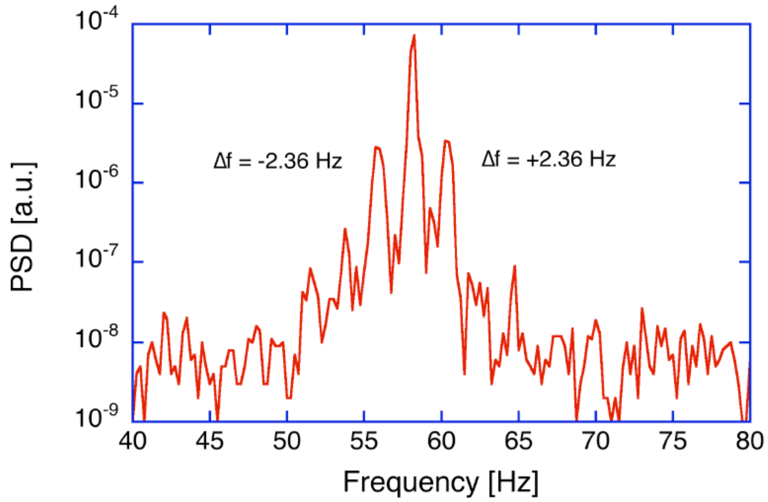
Infrared Operation of a He-Ne Gyroscope

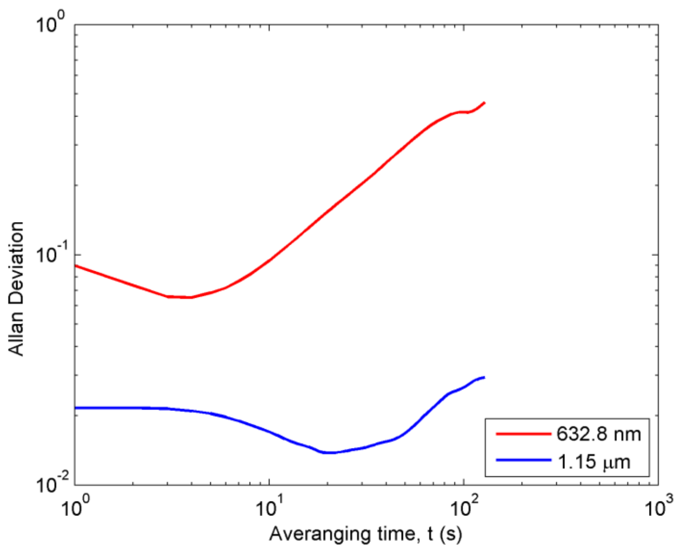
- Crystalline coating mirrors (AlGaAs)
- Gain medium is a 50:50 mix of ^{20}Ne and ^{22}Ne
  - ^{4}He added to quench the 2s4→2p7 transition
- cavity Q of 3.2×10^{10}

Infrared Operation of a He-Ne Gyroscope



Infrared Operation of a He-Ne Gyroscope



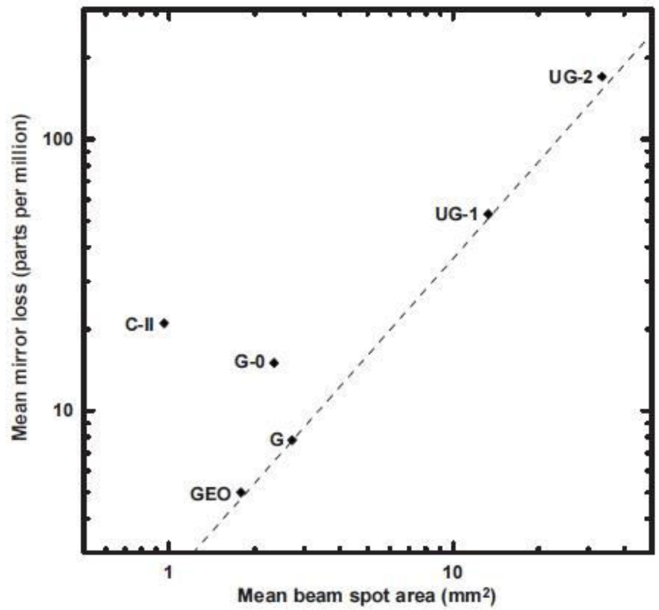


- First 1.15 micron gyroscope to unlock on the bias provided by Earth rotation alone.
- In a comprised environment, it seems to out perform operation at 633 nm.

Why Not Go Further? Go Green… its trendy

- Why use the 632.8 nm transition at all?
- Operation at 543.3 nm gives an automatic 17% increase in scale factor, 10% reduction in optical footprint.
- The cavity Q increases by 17% as

$$Q = 2\pi f_0 \tau$$



543.5 nm	Green	$3s_2 \to 2p_{10}$	0.52
632.8 nm	Red	$3s_2 \to 2p_4$	10.0
3,391.3 nm	Mid-IR	$3s_2 \to 3p_4$	440.0

Conclusions

Portable Sensors: Solid state gyros can run on less than a watt, but need development. However there is a road map.

Big Rings: Ring laser gyroscopes have improved in overall usable sensitivity by around six orders of magnitude in 25 years.

So what is left in the toolbox?

I suggest we are close to the limits of what operation at 632.8 nm can do for us…

Thanks to the ‘many others’

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Mr Robert Thirkettle
Dr Andre Gebauer
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