A Magnetometer for the neutron electric dipole moment experiment

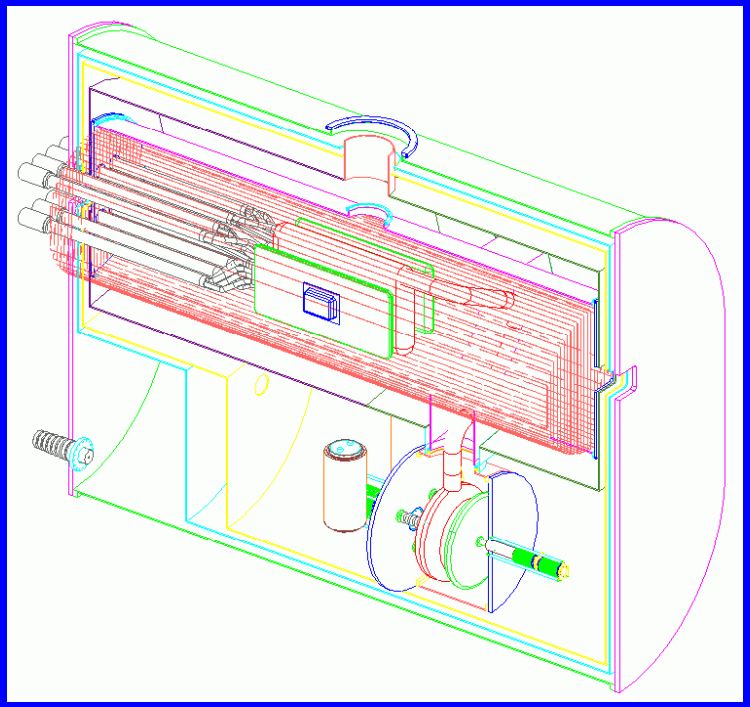
Chris Hovde Southwest Sciences
Dmitry Budker UC Berkeley
Brian Patton UC Berkeley
Eric Corsini UC Berkeley

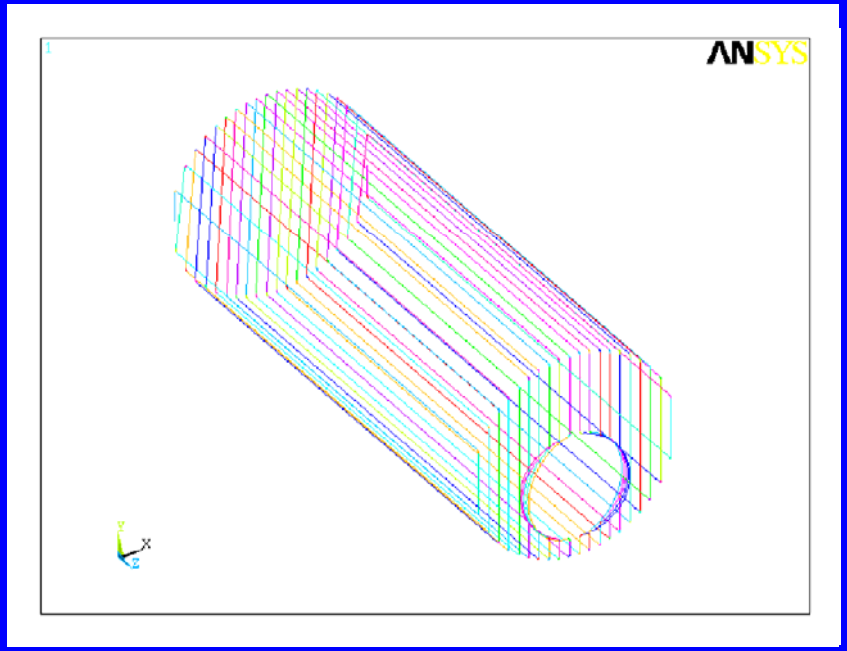
Southwest Sciences conducts R&D in applied spectroscopy

Custom Instruments

Licensed Products

Does the Cos(θ) magnetic coil produce a sufficiently uniform field in target region?



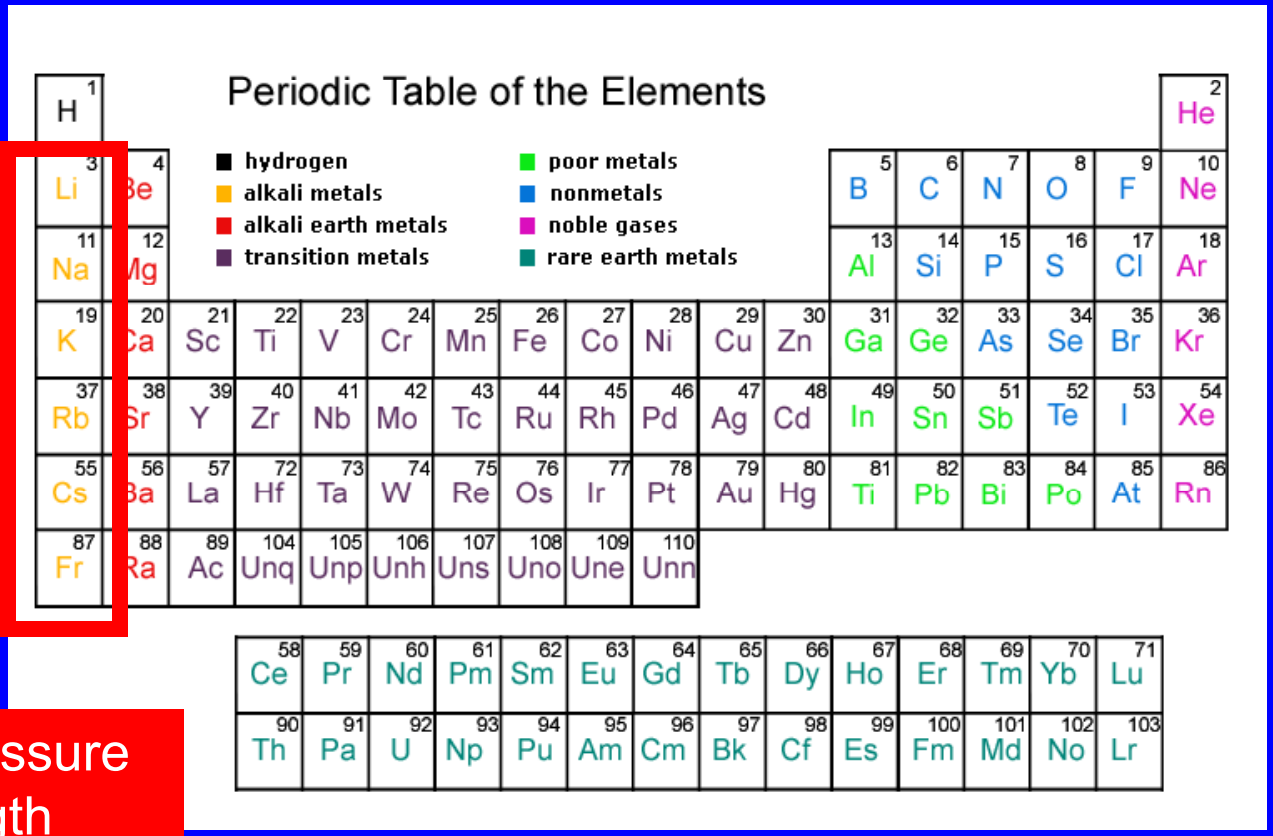


R. E. Mischke, (2001)

Magnetometer needs to be small, sensitive, and accurate

- Size about 1” or less to measure homogeneity of target region with electric field plates in place
- 1 pT sensitivity to 1 uT magnetic field
- Highly reproducible and stable

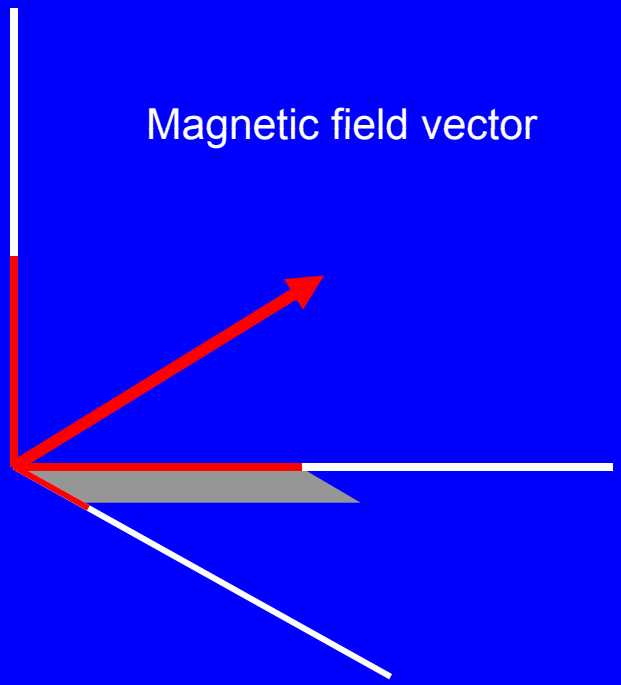
The electron spins in an atomic vapor can be used as a magnetometer.



Highest vapor pressure
Longest wavelength

Alkali metals have one unpaired electron, which precesses in a magnetic field a the Larmor frequency

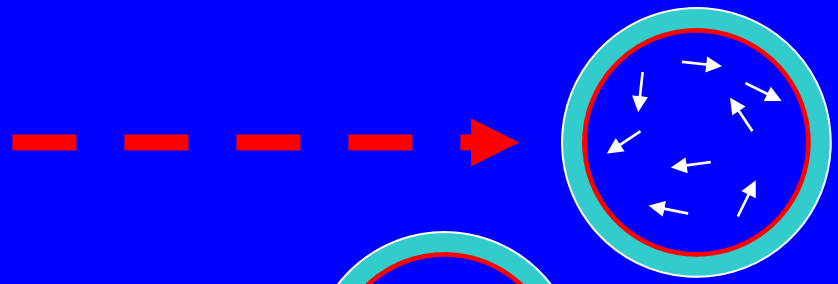
Atomic magnetometers (try to) measure the total magnetic field



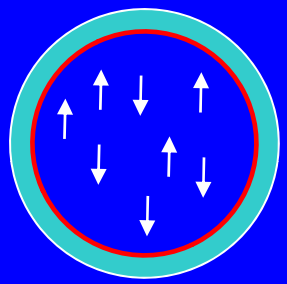
Atomic magnetometers measure length of vector:$(B_x^2 + B_y^2 + B_z^2)^{1/2}$ by measuring Larmor precession frequency.

Other probes (fluxgate, SQUID, Hall) measure vector components B_x, B_y, B_z

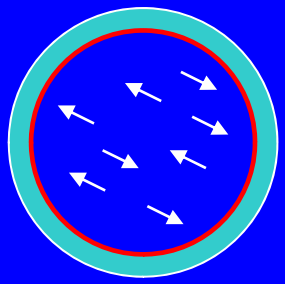
How NMOR works: a modulated laser beam shines on the atoms…



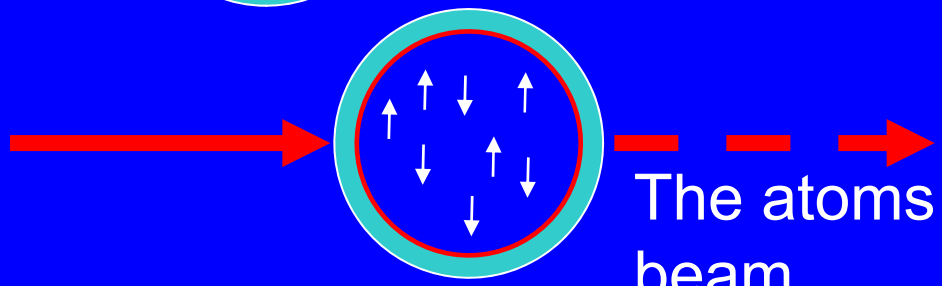
Cs atoms in a specially coated glass bulb



…aligning the atomic spins

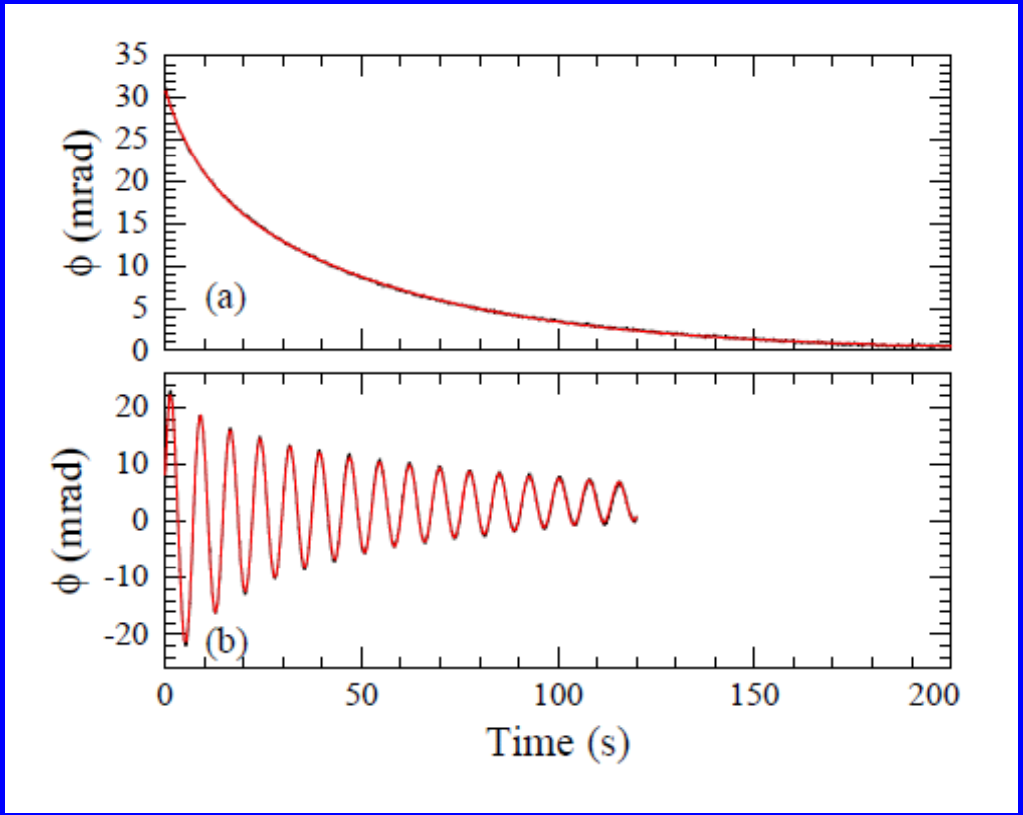


The magnetic field rotates the direction of the spins



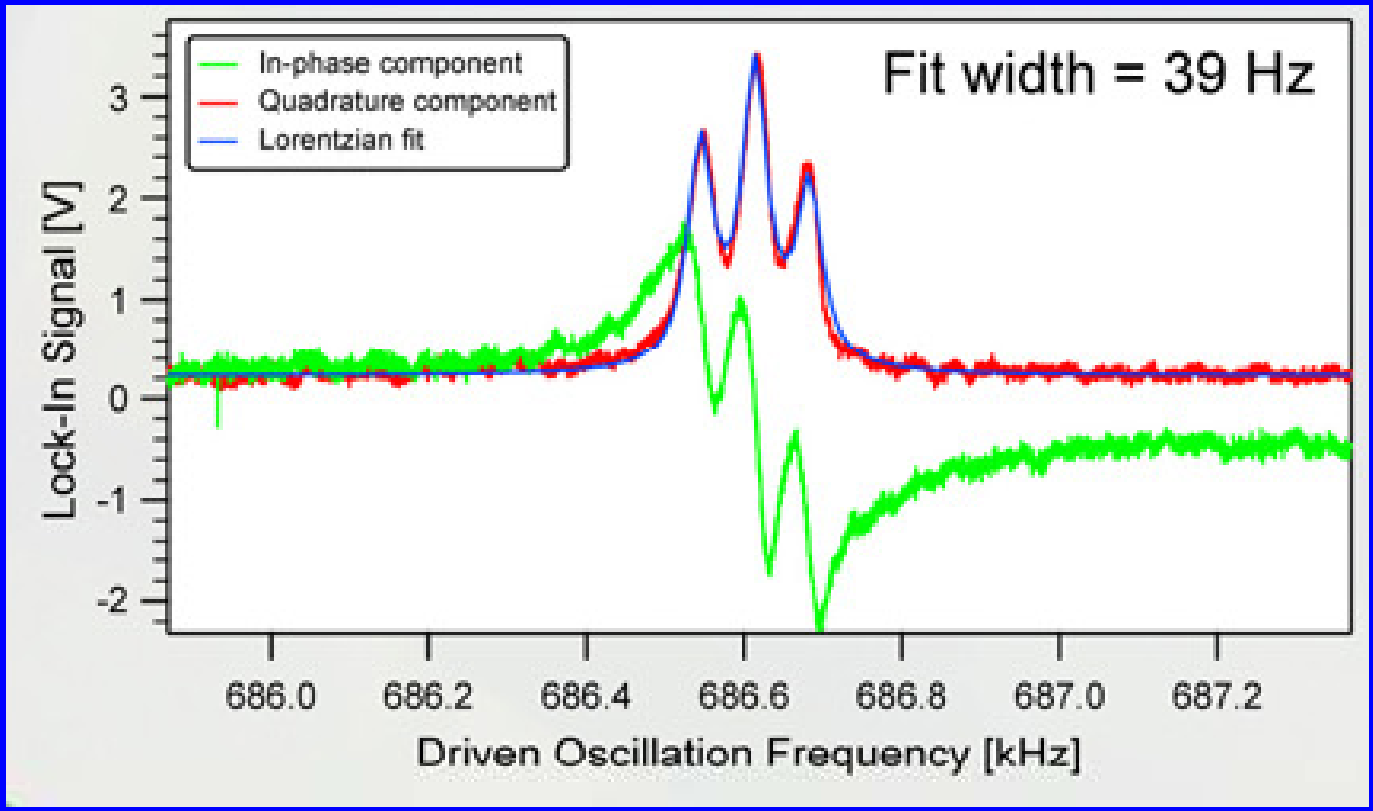
The atoms modulate a probe beam

New cell coating results in very long coherence lifetime



Polarized alkali vapor with minute-long transverse spin-relaxation time

When the modulation frequency matches the Larmor magnetic precession frequency, a strong probe beam signal is observed

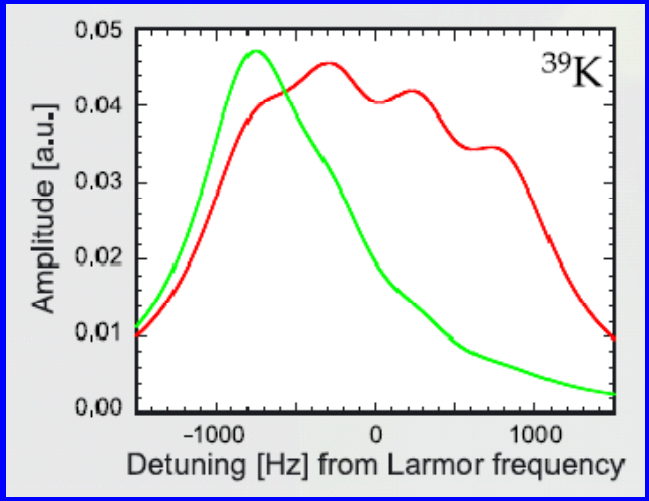


Sources of systematic error

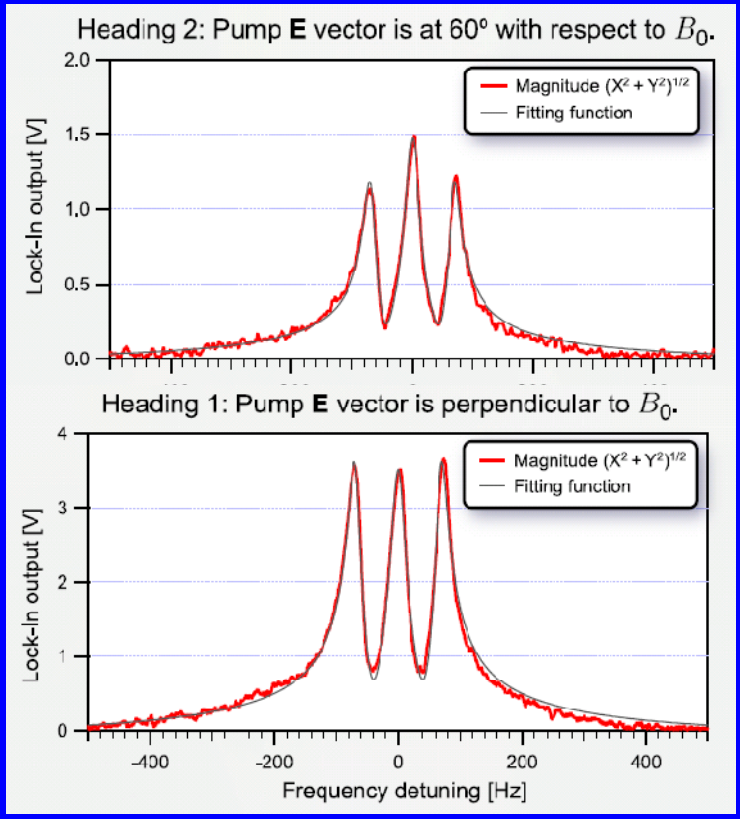
- Stray fields from probe
- Nonlinear Zeeman effect
- Changes in resonance width
- Alignment to orientation conversion
- AC Stark effect
- Imperfect polarization

Alignment magnetometer has higher symmetry, leading to smaller heading errors

Heading error at Earth field, where it is much bigger



Orientation spectrum

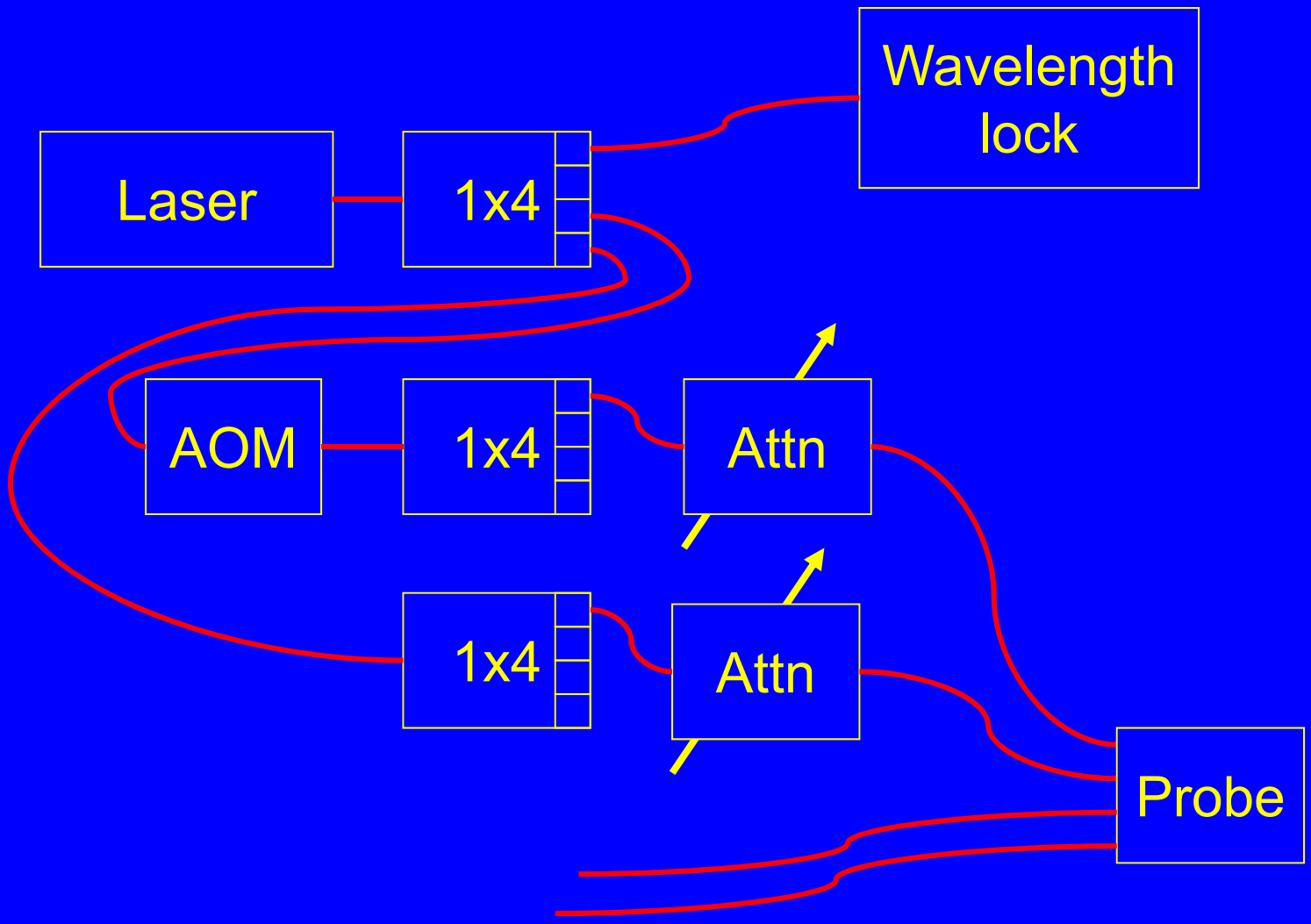


Alignment spectrum

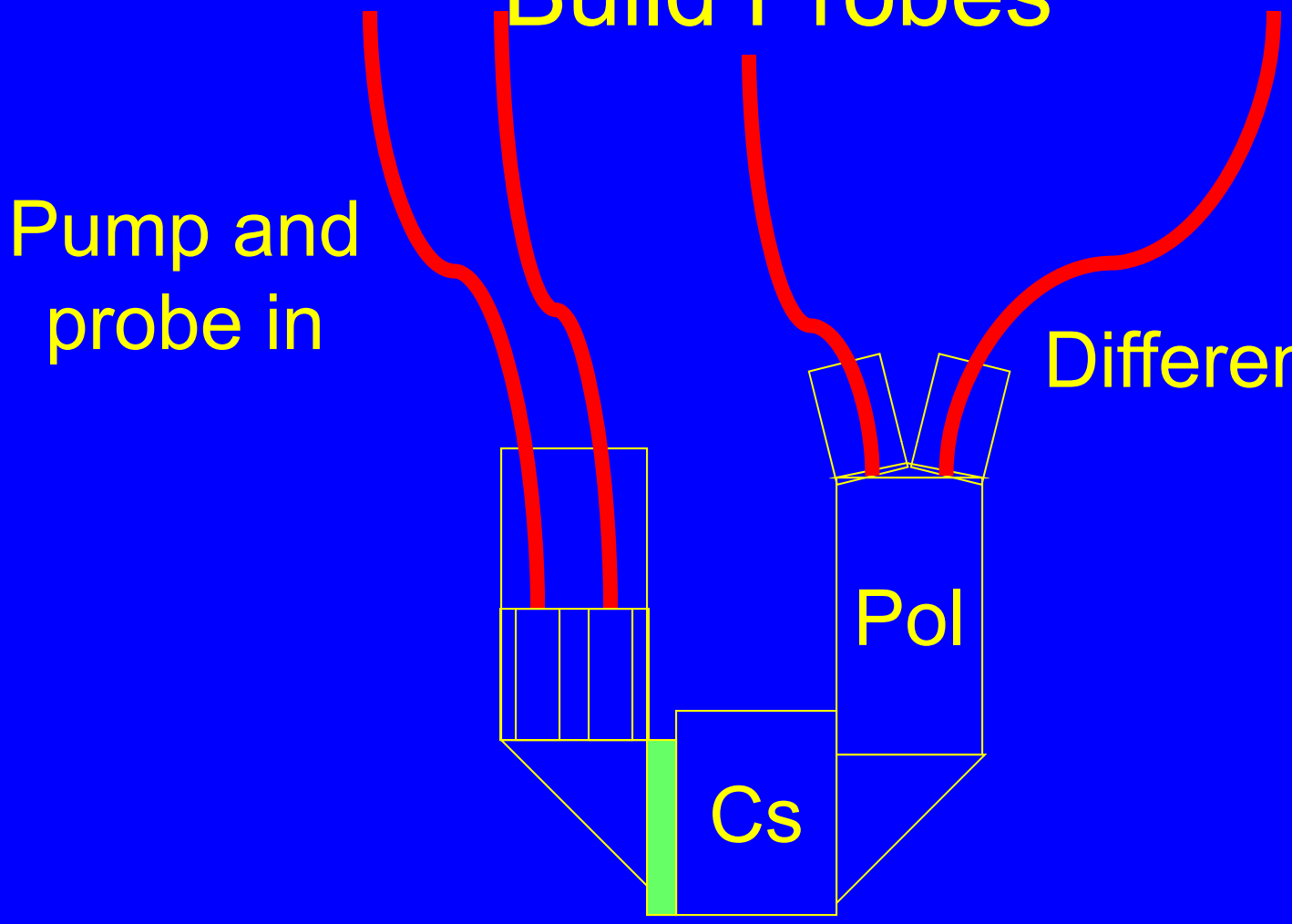
Phase II Tasks

- Build up the optics and electronics
- Build up field probes
- Test probes against each other
- Examine systematic errors in the lab

Build up optics and electronics



Build Probes



Detailed view of the magnetic probe.
Prisms are 10 mm

Summary of progress

- Fiber delivery to multiple measurement channels
- Building up magnetic probe
  - Low noise observed out of fiber
  - Low noise observed coupled into mm fibers
  - Need to put both halves together
- Studying other error sources
  - NLZ and heading well understood
  - Alignment to orientation making progress
  - AC Stark effect needs to be be done
- New cell coating needs further testing