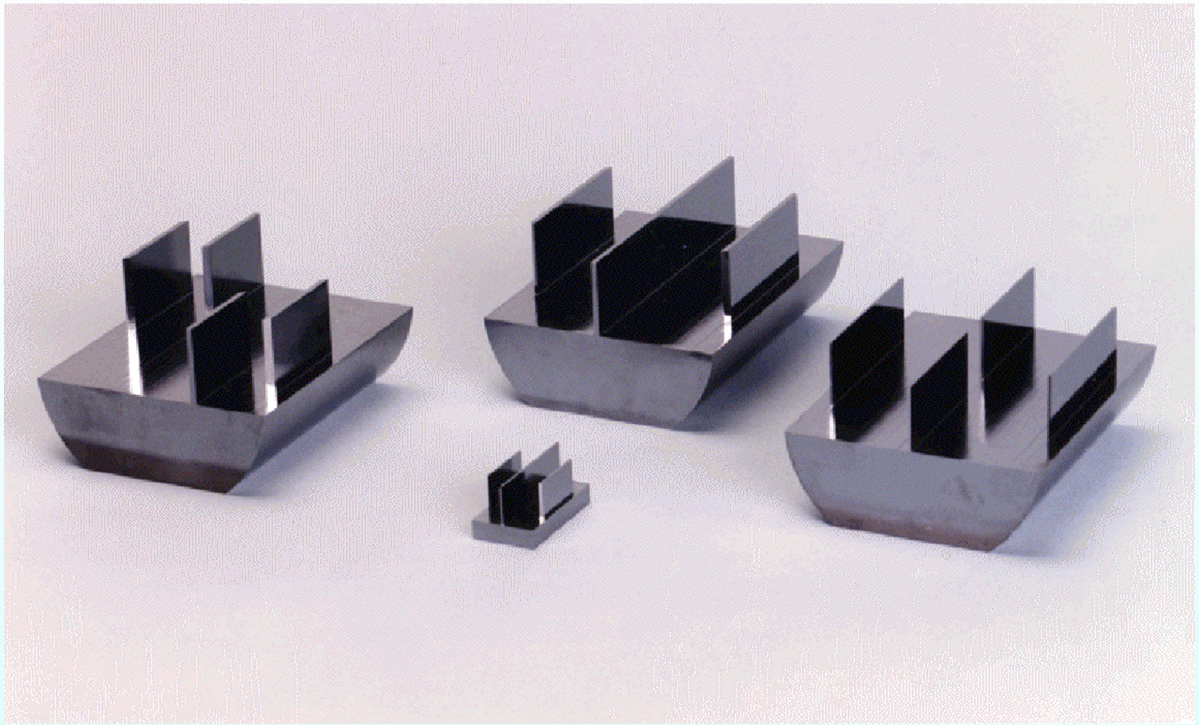
Neutron Interferometry Search for Strongly-Coupled Chameleons

W.M. Snow (Indiana University)
M. Arif, M. Huber, D.L. Jacobson (NIST)
D. Pushkin (Institute for Quantum Computing)

What is a neutron interferometer?
Use for chameleon search: recent developments

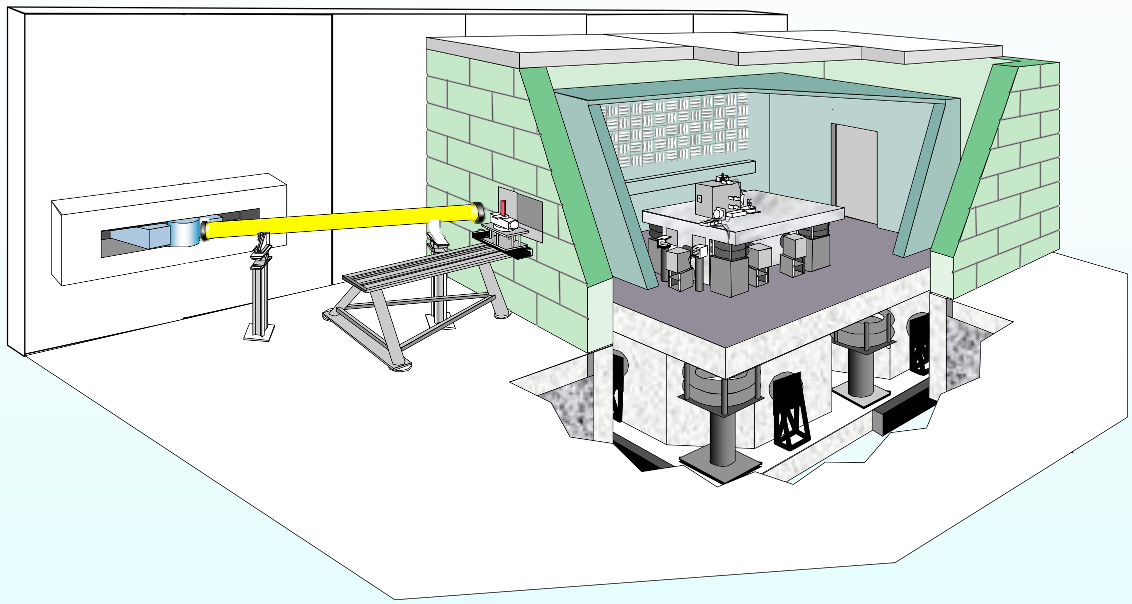
Thanks to G. Pignol, P. Brax

Perfect Crystal Neutron Interferometer



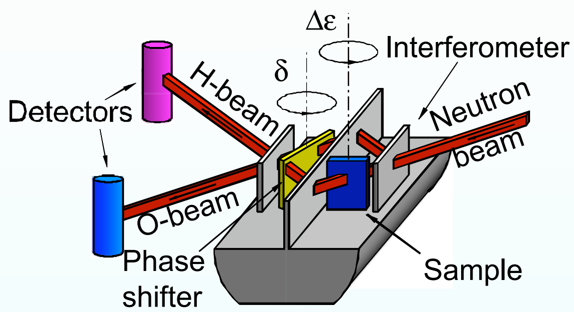
- 5 - 15 cm in length and 2 - 10 cm in width
- Blades are typically 0.5 to 3 mm thick
- Dimensional tolerance: A few micro-meters
- Typical neutron transit is time 50-100 micro-sec

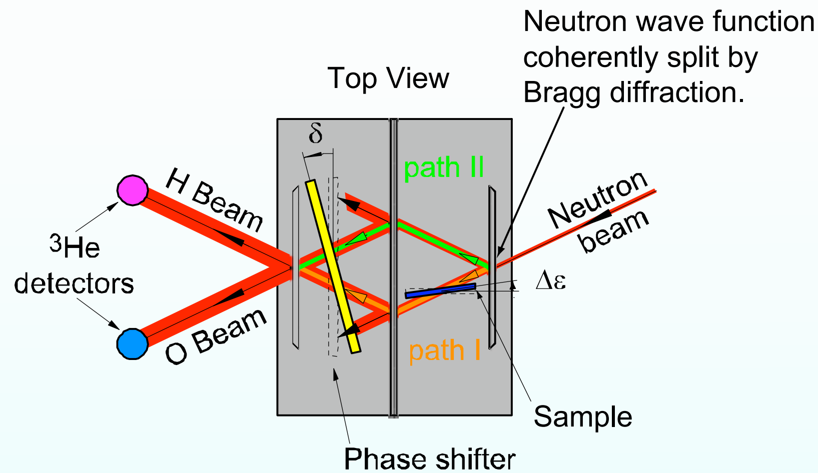
Neutron Interferometer and Optics Facility (NIOF)

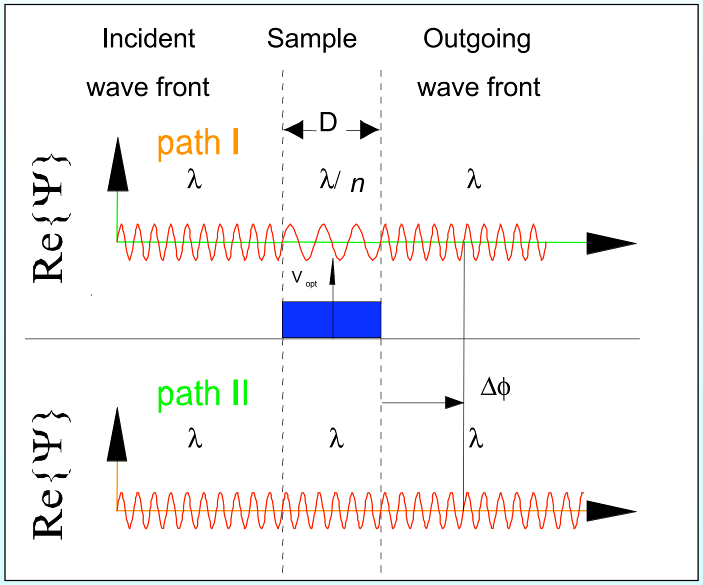


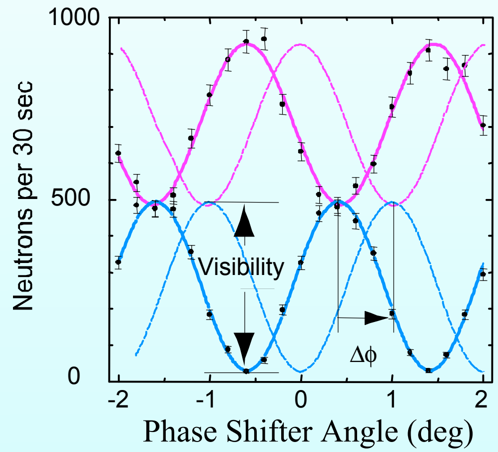
Contrast	> 90%
Phase Stability:	0.25^{o} / day (best value)
Monochromator:	PG (002), Parallel double crystal geometry
Beam Intensity:	2.10^{5} n/cm^{2} .sec (at the interferometer)
Vibration :	$< 10^{-7}$ g
Stability:	< 2 micro-meter (linear)
	< 1 micro-rad (rotation)
Temperature:	$< 0.1^{o}$ C
Polarizer:	Super mirror transmission type
Polarization:	> 98 %

How a neutron interferometer works





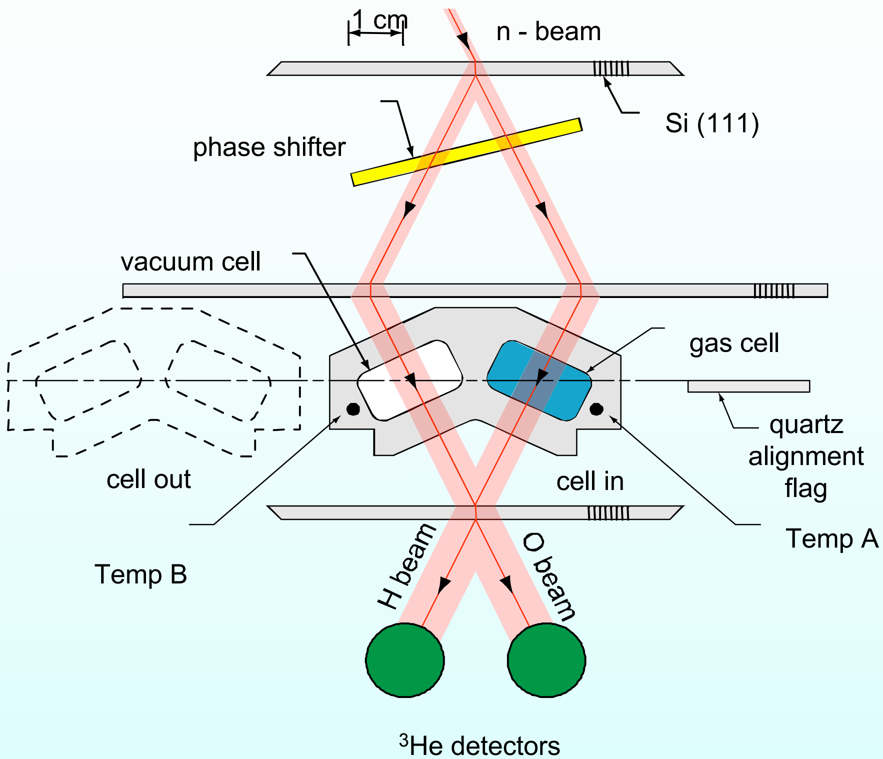


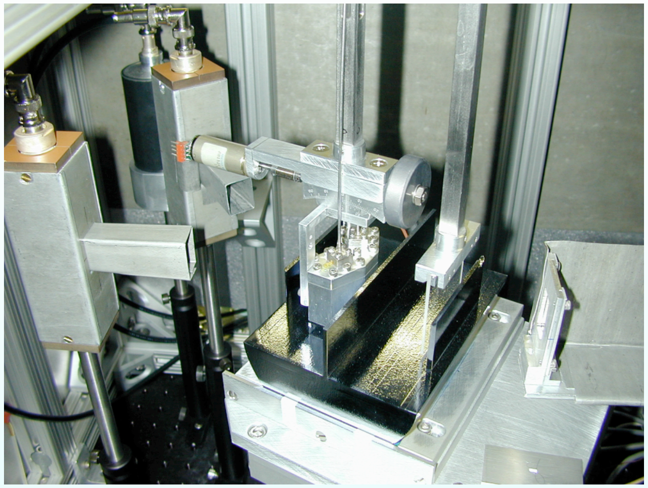


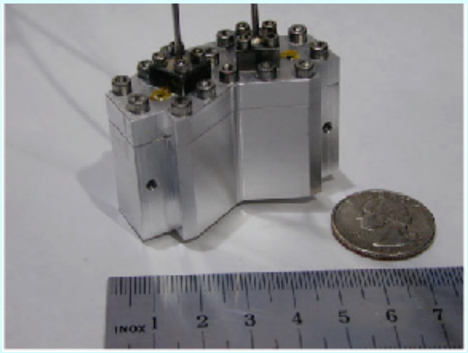
$$\Delta\phi = -\lambda NbD$$

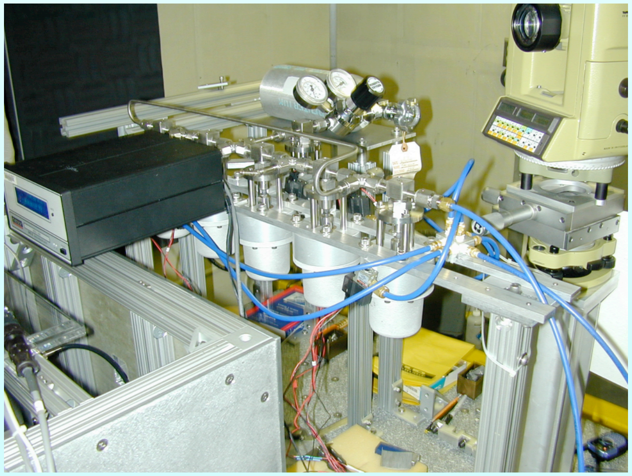
- Visibility > 90%
- Only neutron optics device which can directly measure the phase shift.

Setup for measuring scattering length of gas samples





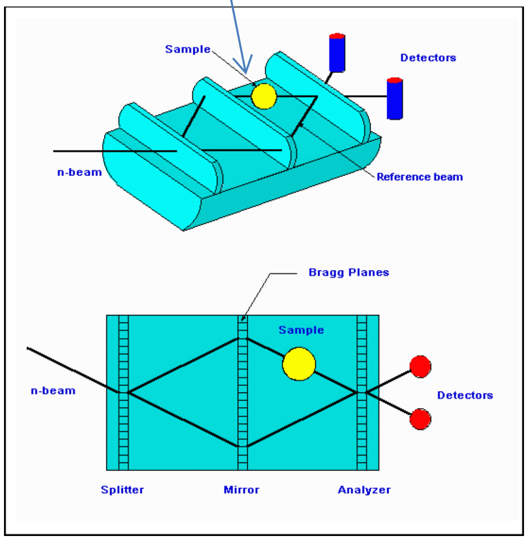




Neutron interferometry

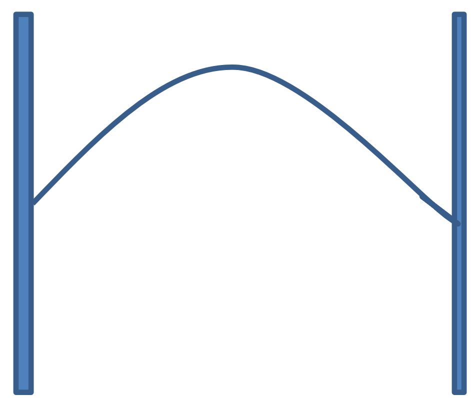
Chameleon bubble

Brax-Pignol, to appear.



One of the beams traverses a chamber where the chameleon leads to a change of the phase

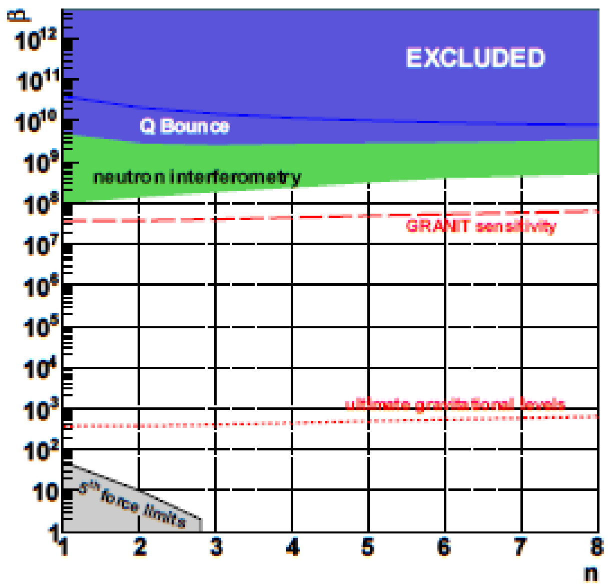
$$\delta\Phi = \int dx \frac{\beta}{m_{\rm Pl}} \frac{m^2 \phi(x)}{k}$$



Chameleon bubble

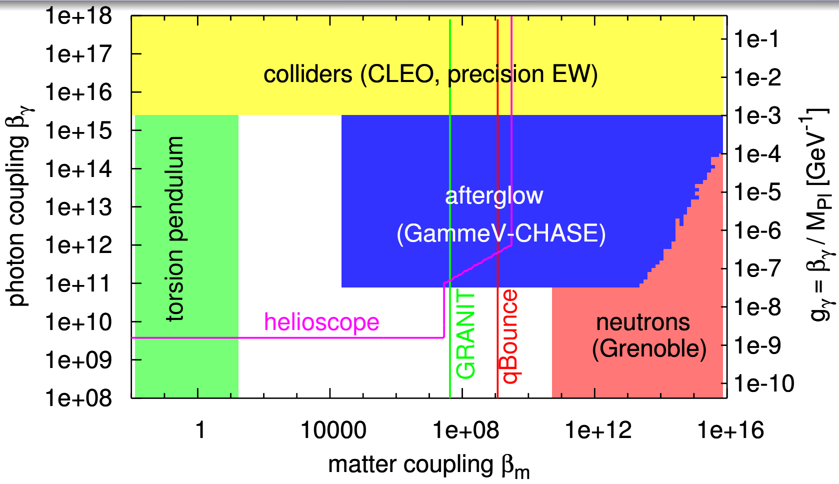
$$\delta\Phi \sim \beta \frac{m^2}{m_{\rm Pl} k} (d\Lambda)^{(4+n)/(2+n)}$$ vacuum

Interferometry is competitive with current bouncing neutron experiments.



Interferometry vs GRANIT

CHASE constraints on $V(\phi) = M_\Lambda^4(1 + M_\Lambda/\phi)$



Theory: *AU, Steffen, Chou, PRD* **86***:035006(2012)[arXiv:1204.5476],*
AU, Steffen, Weltman, PRD **81***:015013(2010)[arXiv:0911.3906]*

Experiment: *Steffen, AU, Baumbaugh, Chou, Mazur, Tomlin, Weltman, Wester, PRL* **105***:261803(2010)[arXiv:1010.0988]*

Future neutron interferometry experiments for Chameleons

- Repeat with dedicated experiment: straightforward, can get ~1 order of magnitude improvement
- Sensitivity can be improved significantly using neutron Fabry-Perot cavities and larger-area interferometers
- Technical developments also of interest for quantum computing research