Changes in effective points of reflection in the ALPS II regeneration cavity

Dennis Schmelzer, Kanioar Karan, Li-Wei Wei, Benno Willke

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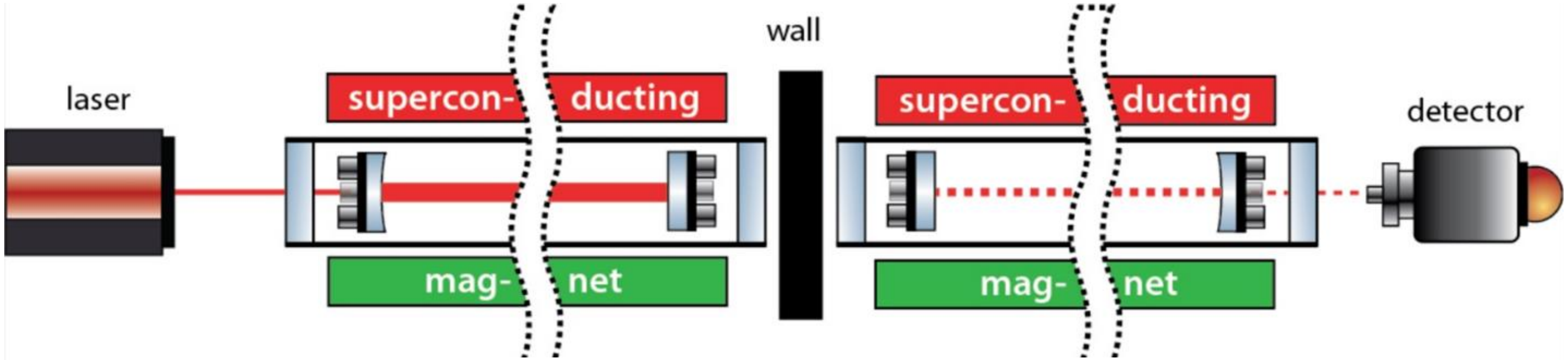
DESY 2018

Talk by Dennis Schmelzer, M.Sc.

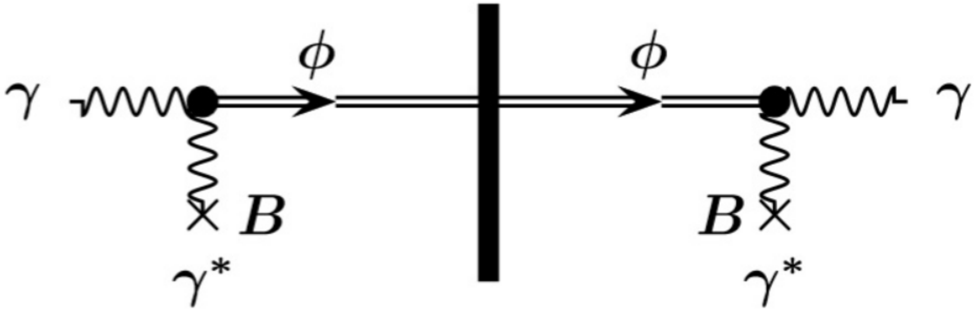
Light-Shining-Through-A-Wall (LSW) concept

ALP Production Cavity (PC)

Photon Regeneration Cavity (RC)



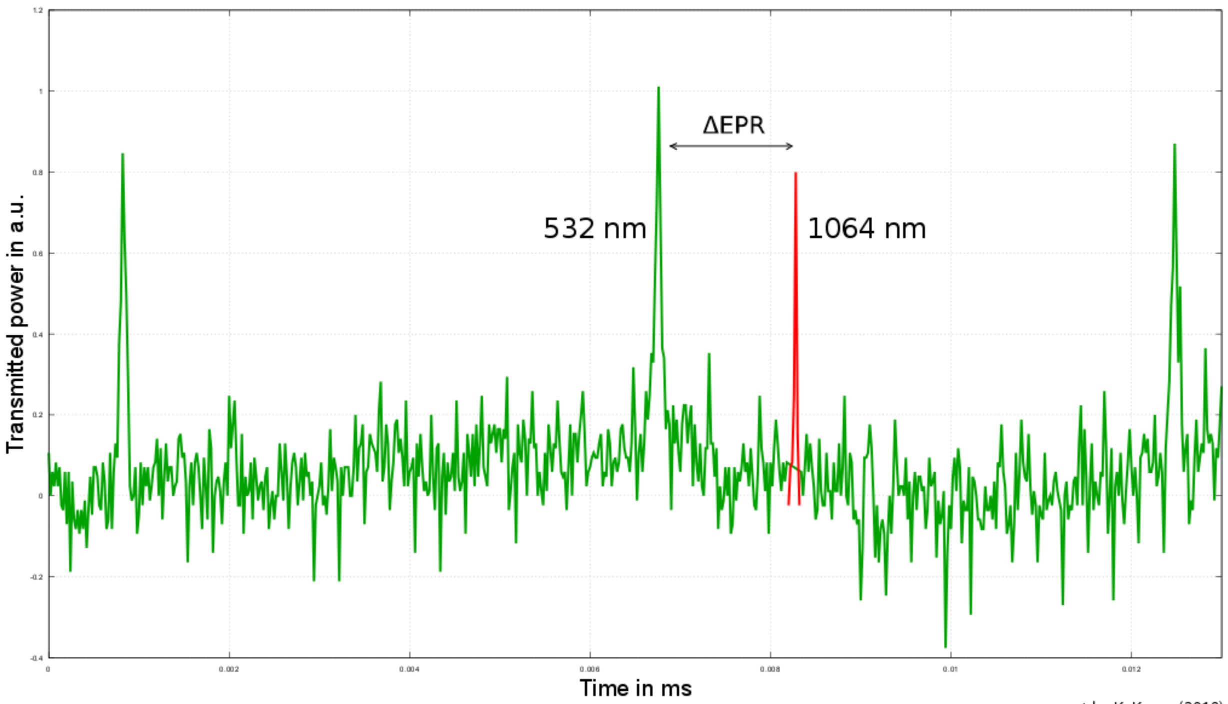
Feynman diagram of the LSW concept



- Photons oscillating into ALPs in the PC
- ALPs can pass through the wall
- ALPs oscillating back into photons in the RC
- Detection with a single-photon detector

Effective point of reflection (EPR)

- LSW experiment with infrared light (1064 nm)
- RC is length controlled with a 532 nm beam
- Mirrors of RC are specified for IR and green
- EPR depends on wavelength
- Control beam probes a different cavity length than the regenerated ALP signal beam
- ΔEPR is compensated with an offset in the control loop

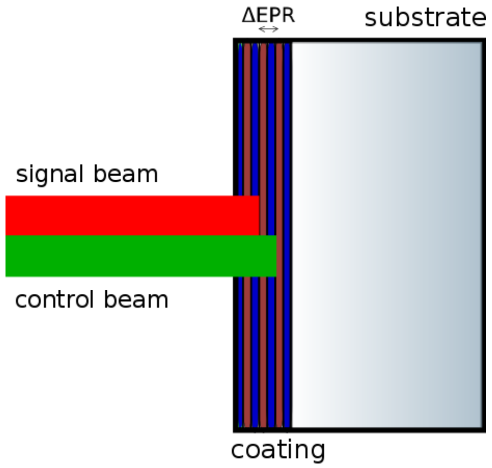


measurement by K. Karan (2018)

RC scan of 1 m prototype at AEI

- ΔEPR = 170 nm

Temperature-induced changes in EPR



- ΔEPR depends on temperature
- Requirement for ALPS IIc:
  Change of ΔEPR < 1 pm over days
  for 0.2 K temperature stability

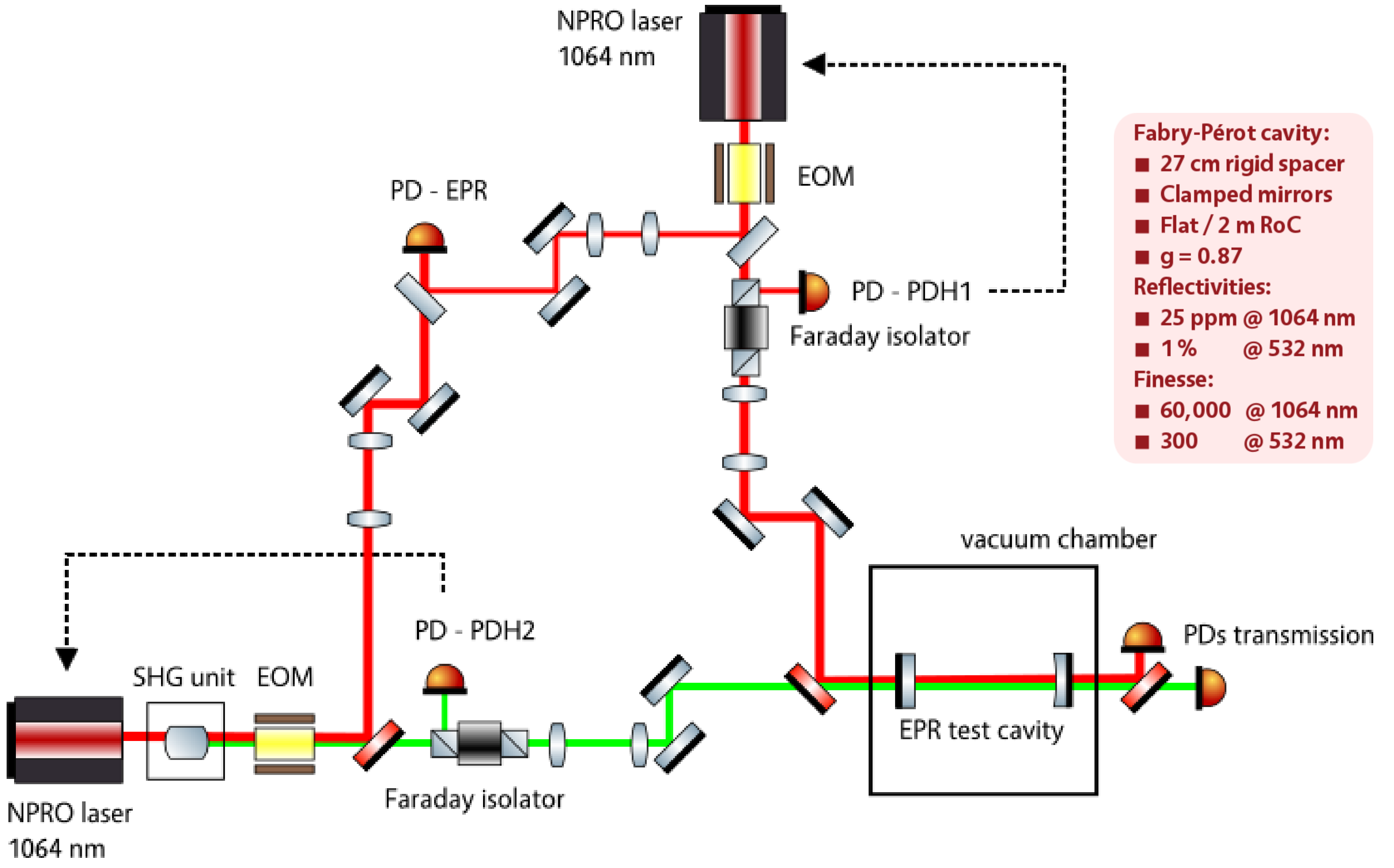
$$\frac{d\Delta\Phi}{dT}\cdot\Delta T_{max}=\underbrace{\left|\frac{d\Phi_{532}}{dT}-2\cdot\frac{d\Phi_{1064}}{dT}\right|}_{\text{coating design}}\cdot\underbrace{\Delta T_{max}}_{\text{environment control}}<2.88\,\mu\text{rad}\ (0.5\,\text{pm})$$

- phase stability per mirror

coating design

environment control

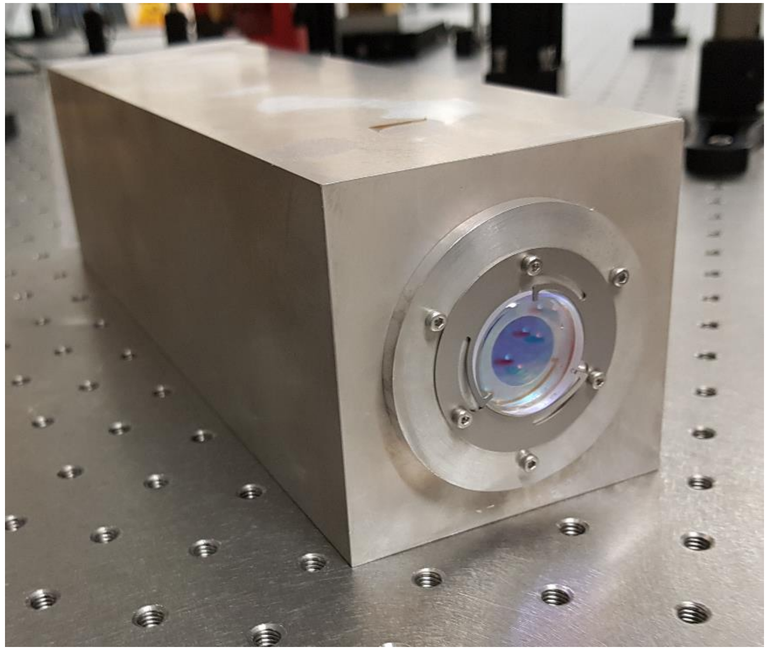
Experimental setup to measure EPR changes



Fabry-Pérot cavity:
- 27 cm rigid spacer
- Clamped mirrors
- Flat / 2 m RoC
- g = 0.87

Reflectivities:
- 25 ppm @ 1064 nm
- 1 % @ 532 nm

Finesse:
- 60,000 @ 1064 nm
- 300 @ 532 nm



Goal:
- Find mirror coatings with small enough temperature dependence of the EPR not to limit the ALPS IIc sensitivity

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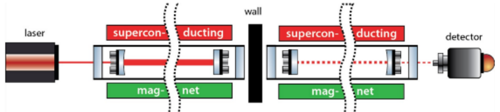
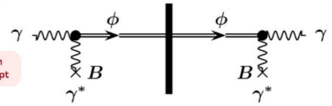
Light-Shining-Through-a-Wall (LSW)





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Any Light Particle Search (ALPS) II

Collaboration Partners

- Placed in the HERA North tunnel at DESY
- Two 100 meter long cavities
- Both cavities resonate with identical modes
- 30 W laser input power @1064 nm
- Power buildup: 5,000 in PC
  40,000 in RC
- 10 HERA dipole magnets per cavity: 468 Tm

Parameter	Scaling	ALPS I	ALPS IIc	Sens. gain
Effective laser power P_{laser}	$g_{a\gamma} \propto P_{laser}^{-1/4}$	1 kW	150 kW	3.5
Rel. photon number flux n_γ	$g_{a\gamma} \propto n_\gamma^{-1/4}$	1 (532 nm)	2 (1064 nm)	1.2
Power built up in RC P_{RC}	$g_{a\gamma} \propto P_{reg}^{-1/4}$	1	40,000	14
BL (before& after the wall)	$g_{a\gamma} \propto (BL)^{-1}$	22 Tm	468 Tm	21
Detector efficiency QE	$g_{a\gamma} \propto QE^{-1/4}$	0.9	0.75	0.96
Detector noise DC	$g_{a\gamma} \propto DC^{1/8}$	0.0018 s^{-1}	0.000001 s^{-1}	2.6
Combined improvements				3082

adapted from Any light particle search II - Technical Design Report (2013)

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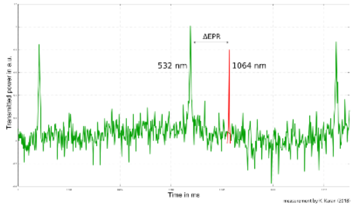

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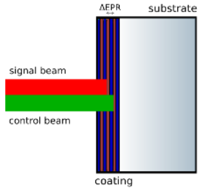

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- Phase stability per mirror:

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coating design — environment control

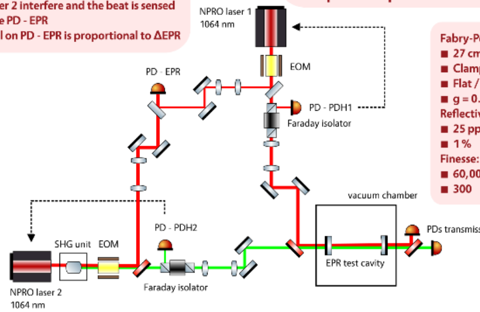
Experimental setup to probe EPR changes for designed coatings

Measurement scheme:

- Laser 1 is frequency locked to the EPR test cavity
- The second harmonic of laser 2 is frequency locked to the EPR test cavity
- Laser 1 and laser 2 interfere and the beat is sensed by photo diode PD - EPR
- The beat signal on PD - EPR is proportional to ΔEPR

Coatings:

- Coating design by the University of Florida, USA: Simulated ΔΦ with 0.2 K temperature stability 2.4 µrad < 2.88 µrad



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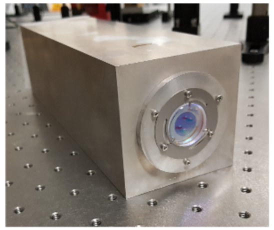

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