Current status of GEMS

GINGER meeting
Padova, 2016-12-16

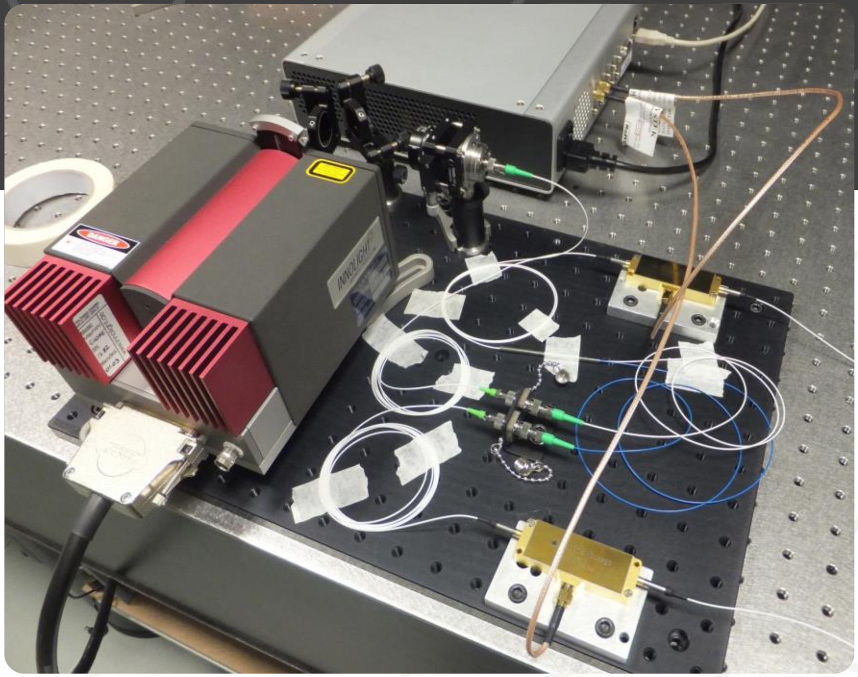
Alberto Donazzan, G. Naletto, M. G. Pelizzo

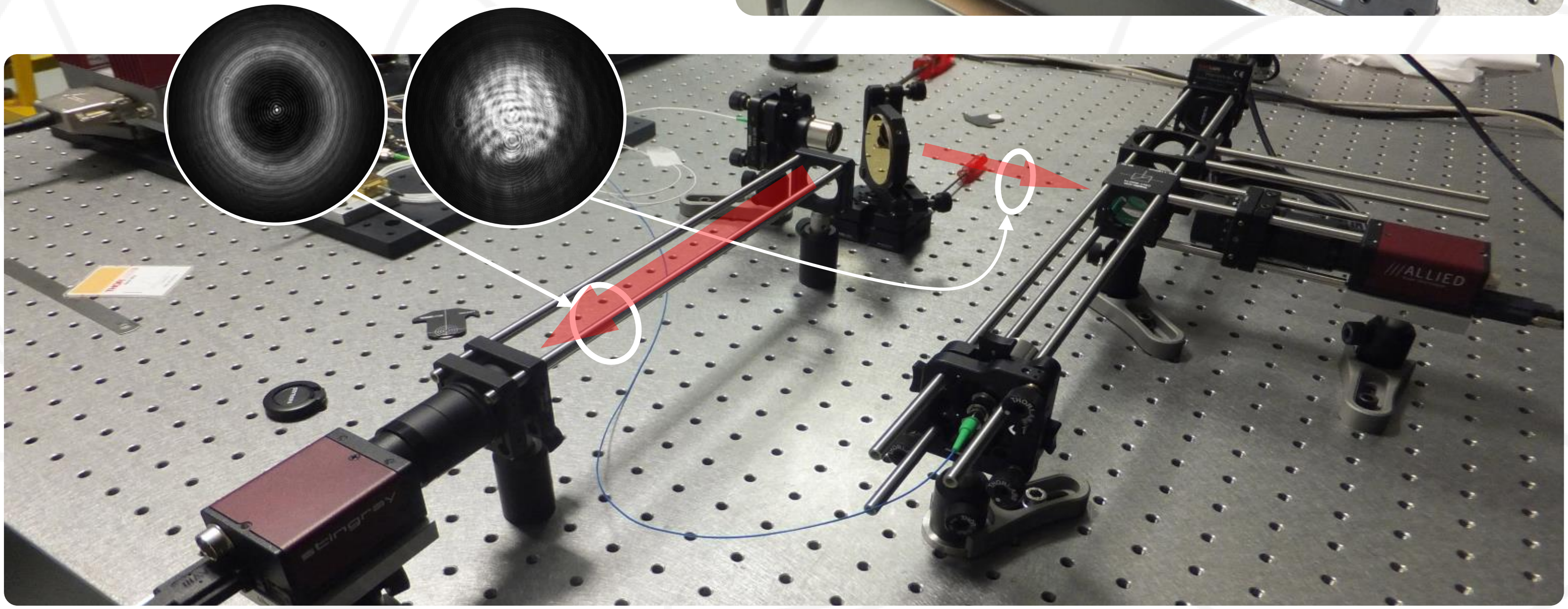
[1] Department of Information Engineering, University of Padova - Padova (Italy)
[2] CNR, Institute of Photonics and Nanotechnology - Padova
[3] National Institute for Nuclear Physics - Padova

Summer Status

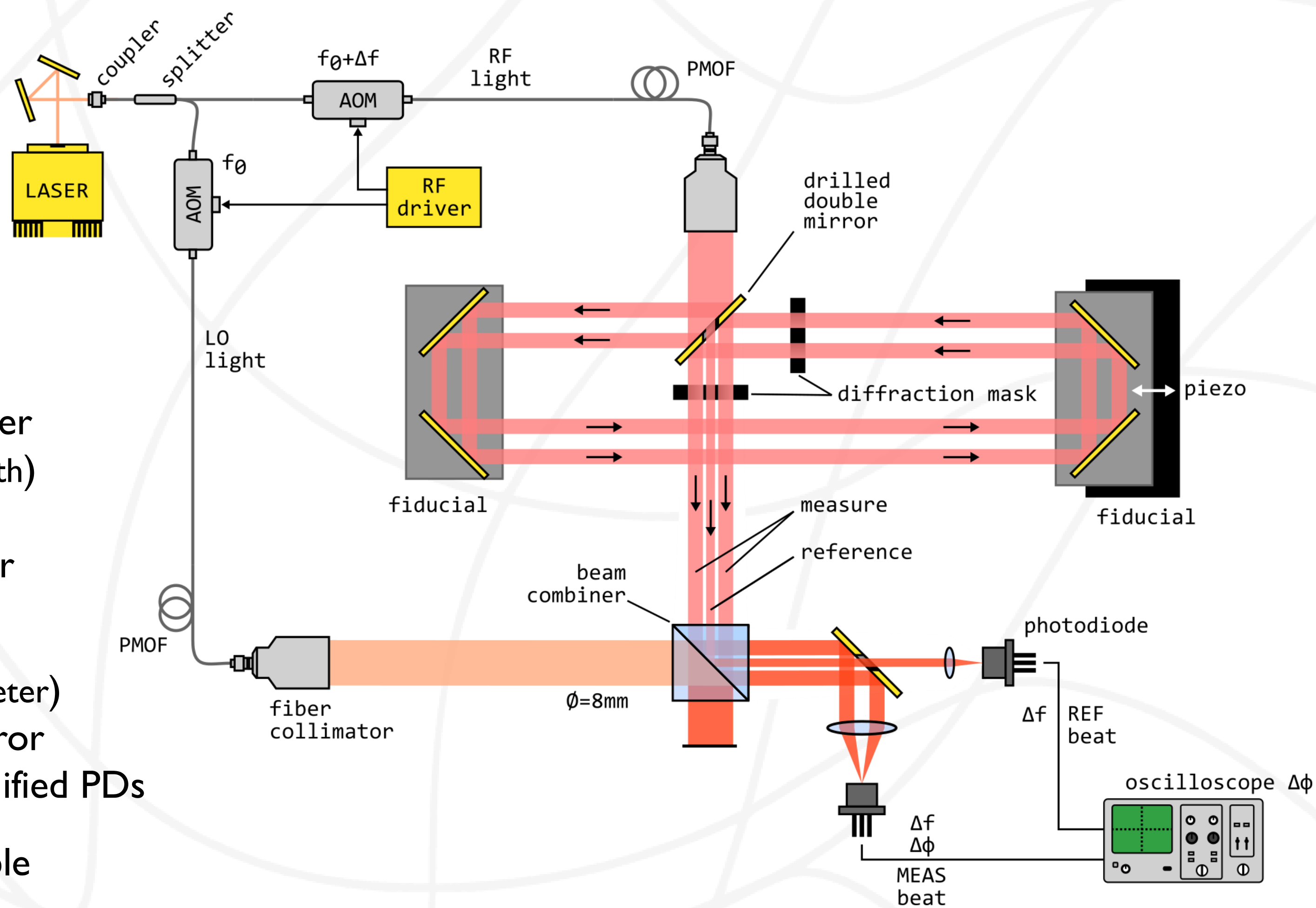
- Heterodyne source aligned and properly working → optical beat with widely tunable Δf

- Beam spoiling along racetrack, due to diffraction and poor retro-reflectors.
- Blocking masks are under study





Prototype layout



Features

- Nd:YAG DPSS cw laser (1064nm, 1kHz linewidth)
- Fiber AOMs
- FPGA based RF driver
- Fiber collimators (8mm $1/e^2$ beam diameter)
- 2" drilled double mirror
- Transimpedance amplified PDs
- Vibration isolated table
- Air environment

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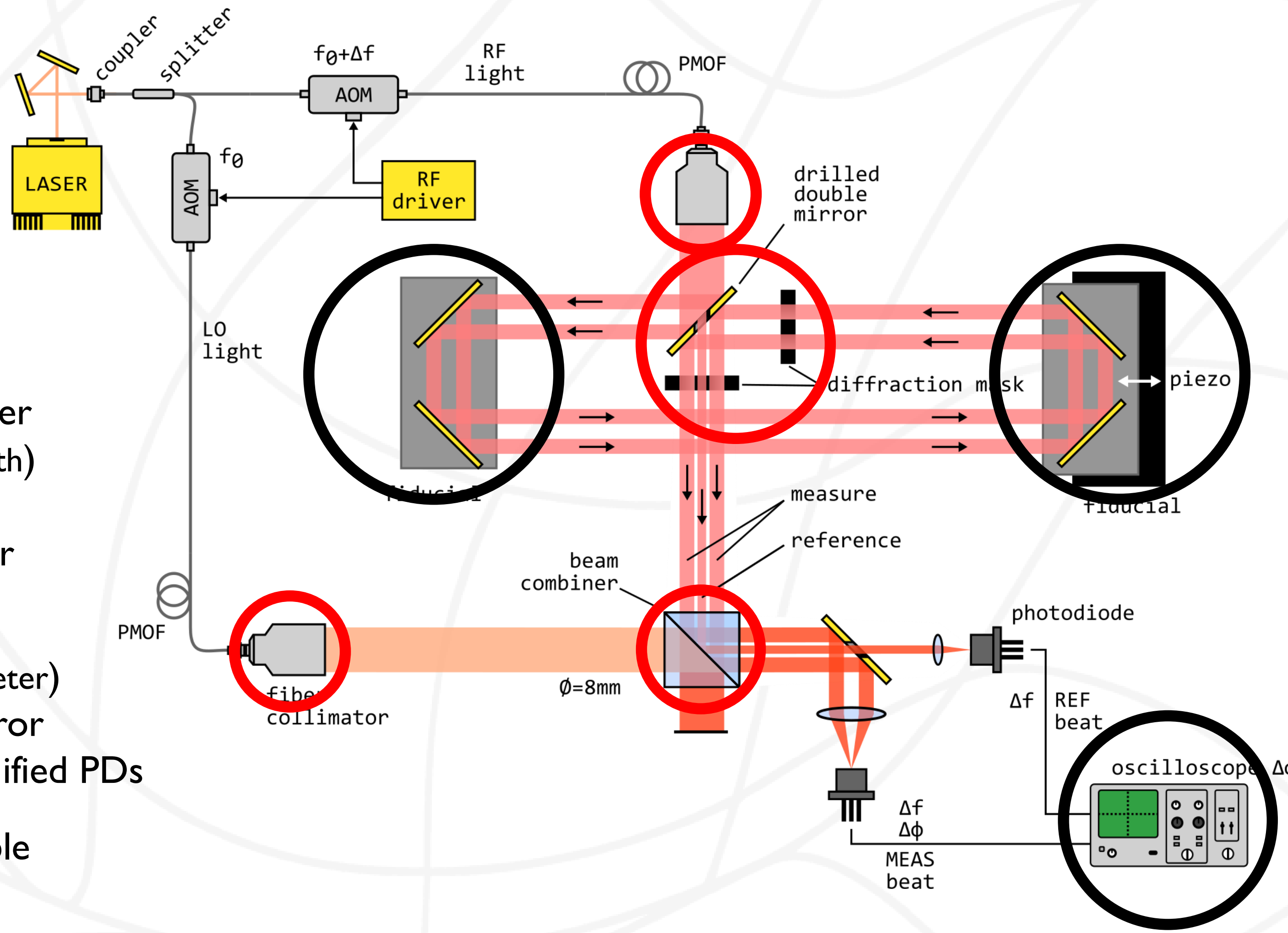

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Standard vs Cancelable Circuit

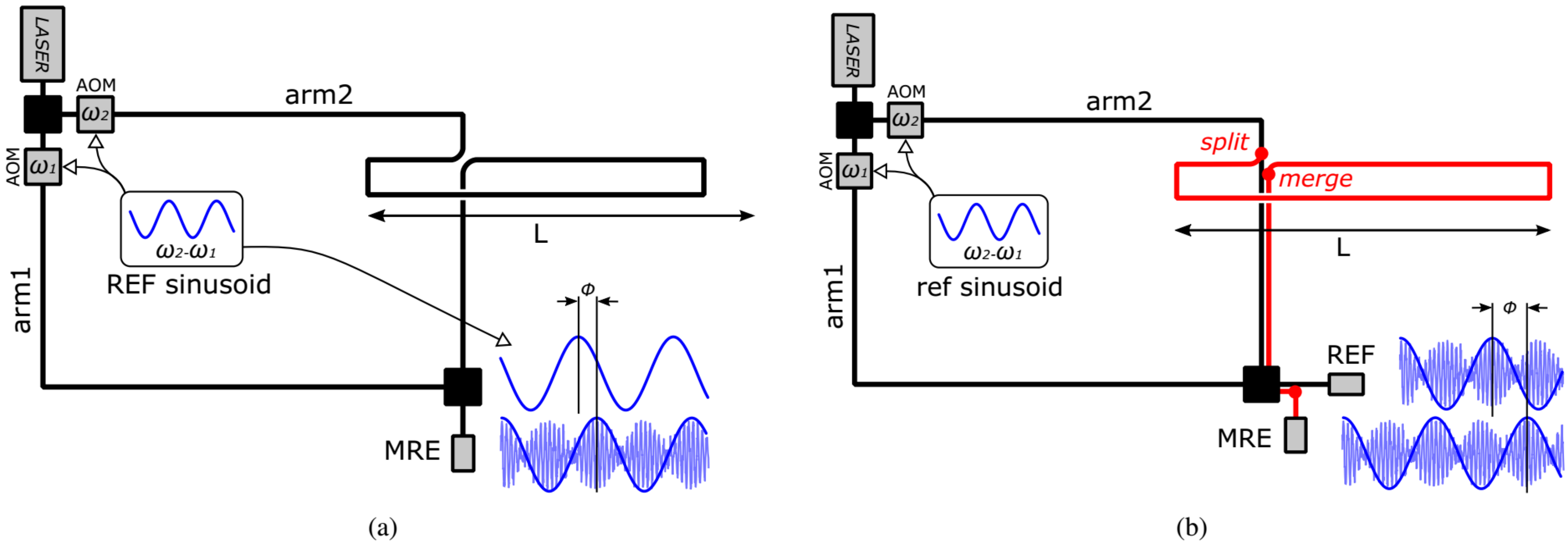


Fig. 1: Simplified optical layout for a displacement heterodyne interferometer placed in between the fiducials defining the concerned distance: (a) standard design and (b) cancelable circuit.

Study of the optical mixing

Reference and measurement beatings are collected by two photodiodes and conveniently converted by transimpedance amplifiers, such that the output signals are ac-coupled voltages defined as:

$$REF(t) = R\sin(\omega_2 t) + M_{leak}\sin(\omega_2 t - \phi)$$
$$MSE(t) = R_{leak}\sin(\omega_2 t) + M\sin(\omega_2 t - \phi)$$

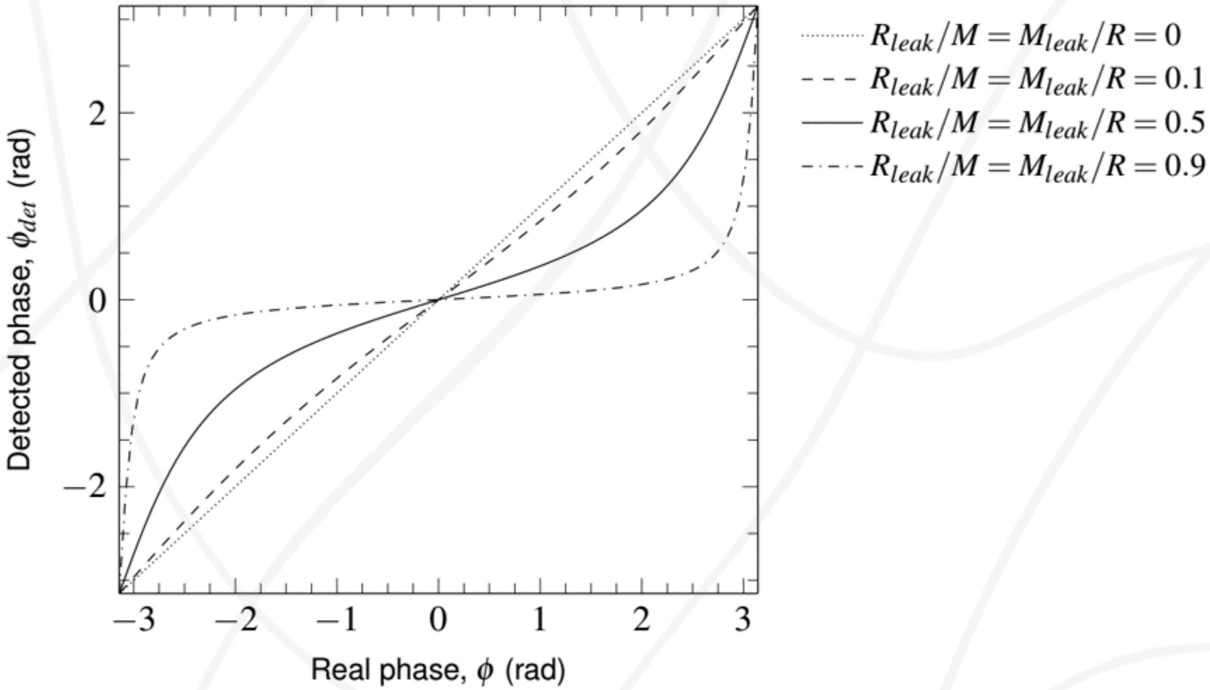
ω_2: optical frequency in arm 2

In the case of zero-crossing phase detection:

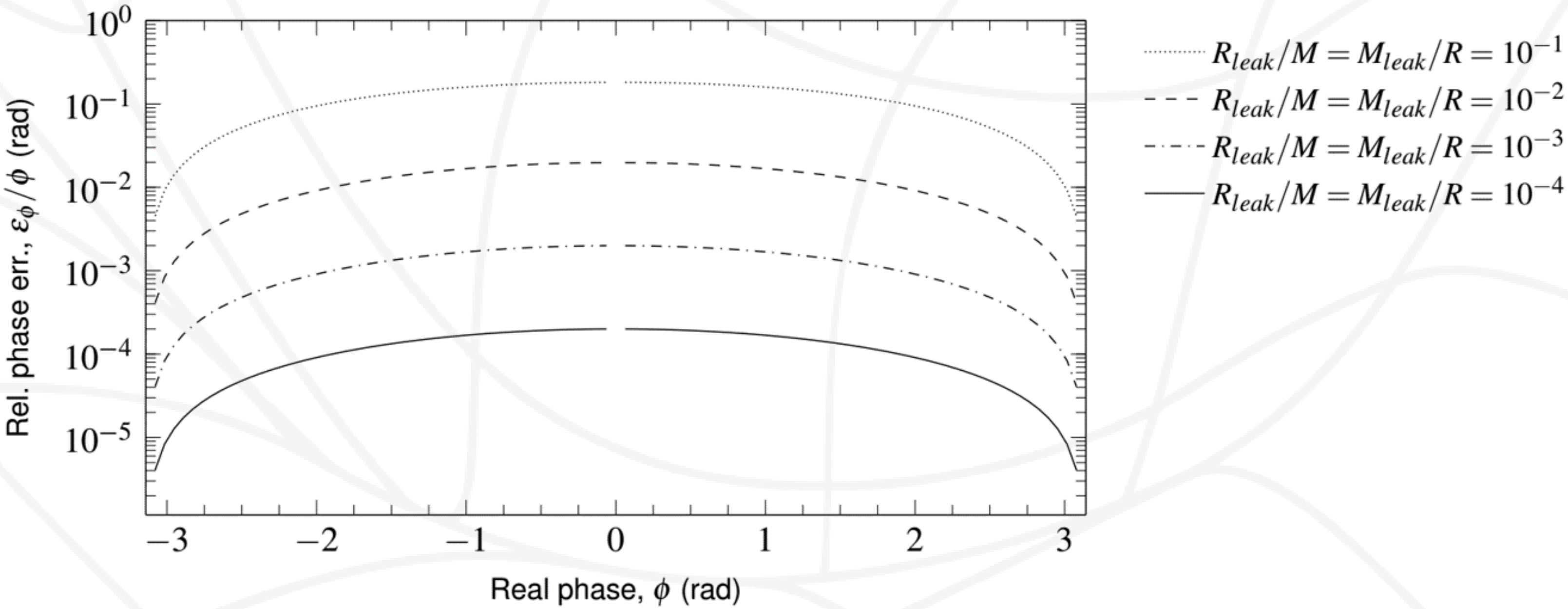
$$REF(t_R) = 0$$
$$MSE(t_M) = 0$$

$$\phi_{det}(\phi) = t_M(\phi) - t_R(\phi)$$
$$= \arccos\left(\frac{R_{leak} + M\cos(\phi)}{\sqrt{{R_{leak}}^2 + 2R_{leak}M\cos(\phi) + M^2}}\right) - \arccos\left(\frac{R + M_{leak}\cos(\phi)}{\sqrt{R^2 + 2RM_{leak}\cos(\phi) + {M_{leak}}^2}}\right)$$

which simplifies to $\phi_{det} = \phi$ in the ideal case of $R_{leak} = M_{leak} = 0$.



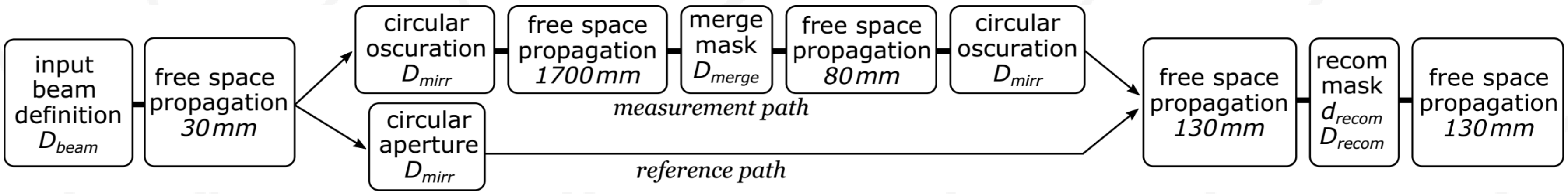
Detected phase, ϕ_{det} (rad)
Real phase, ϕ (rad)
$R_{leak}/M = M_{leak}/R = 0$
$R_{leak}/M = M_{leak}/R = 0.1$
$R_{leak}/M = M_{leak}/R = 0.5$
$R_{leak}/M = M_{leak}/R = 0.9$

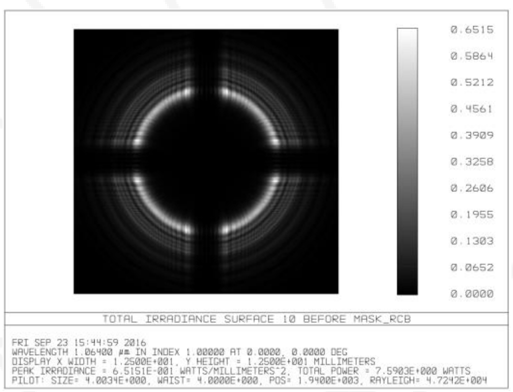


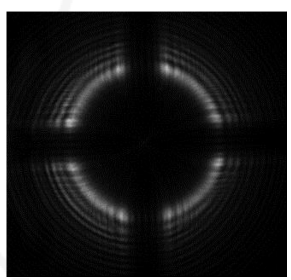
Rel. phase err., ε_ϕ/ϕ (rad)
Real phase, ϕ (rad)
$R_{leak}/M = M_{leak}/R = 10^{-1}$
$R_{leak}/M = M_{leak}/R = 10^{-2}$
$R_{leak}/M = M_{leak}/R = 10^{-3}$
$R_{leak}/M = M_{leak}/R = 10^{-4}$

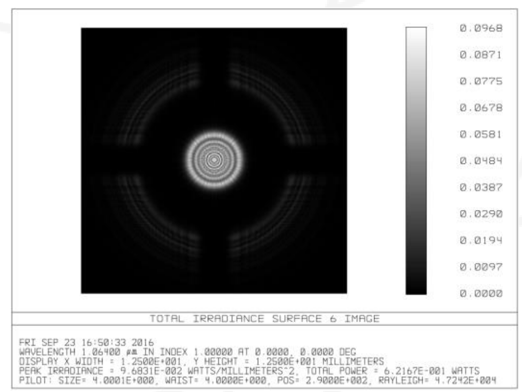
Simulations of Beam Propagation

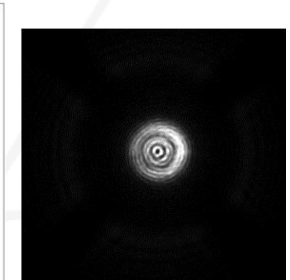
Zemax® Physical Optics Propagation (POP) tool: uses diffraction calculations to propagate a wavefront through an optical system surface by surface.





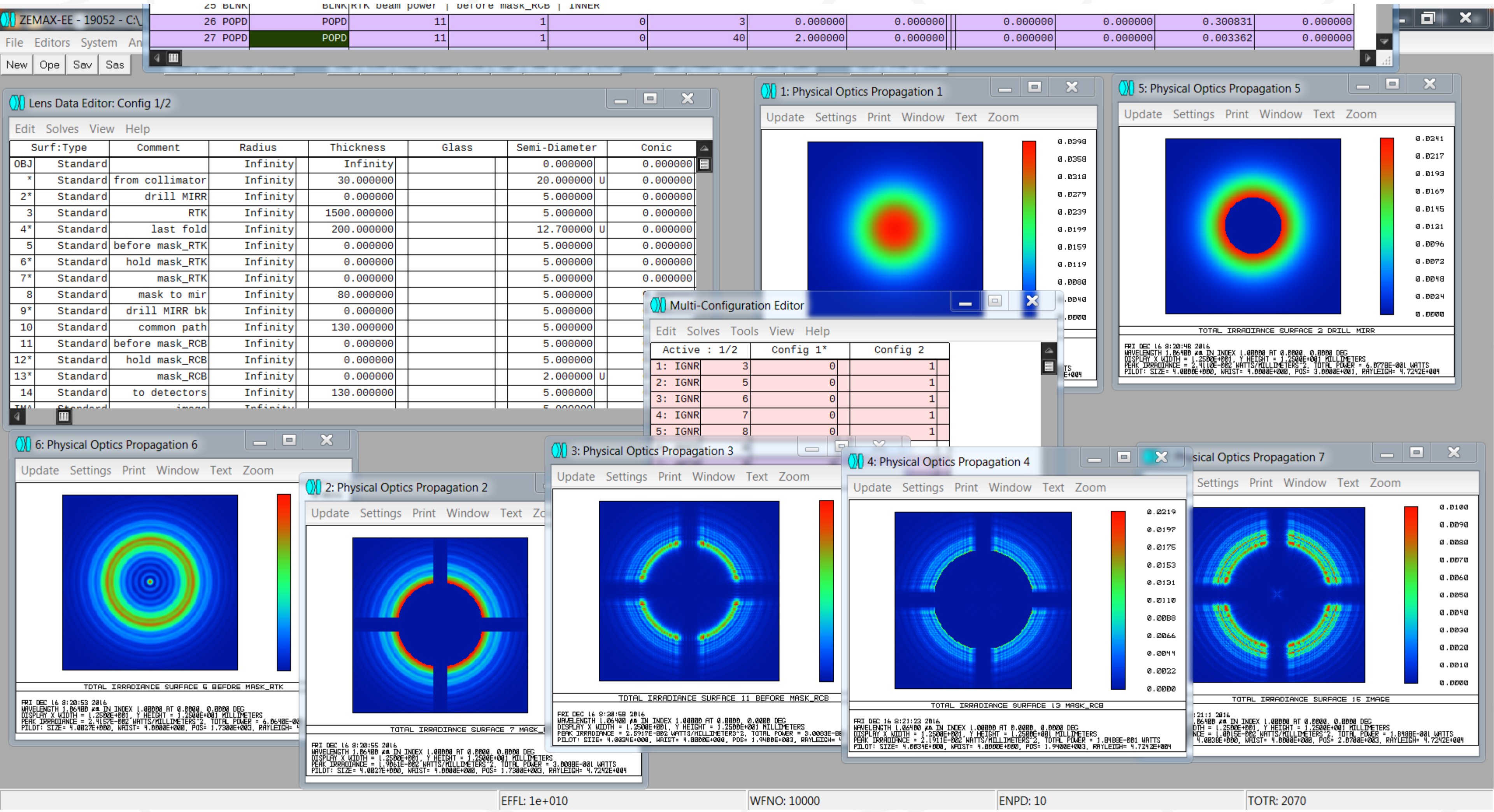






Good agreement between POP model and experimental data!

Zemax® Physical Optics Propagation

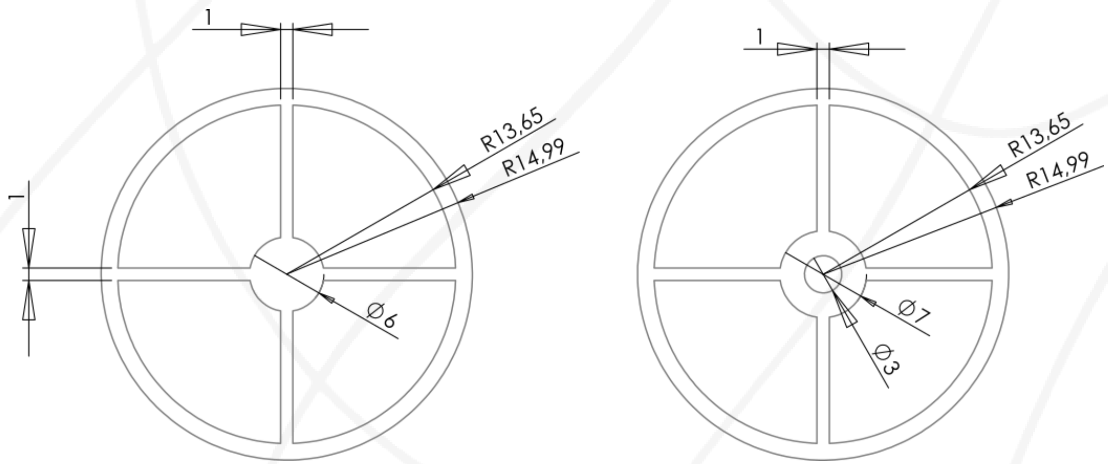


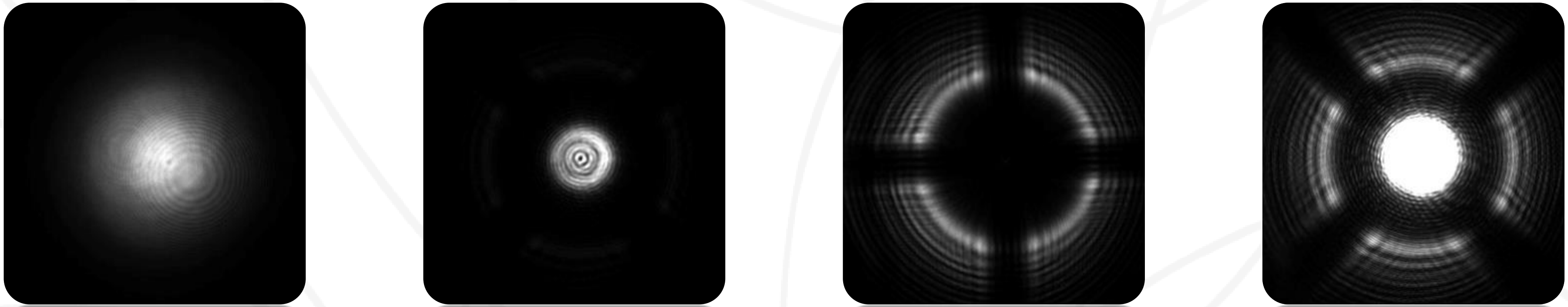
Simulation results

Configuration	D_{mirr} [mm]	D_{merge} [mm]	d_{recom} , D_{recom} [mm]	R_{leak} / M	M_{leak} / R	ε_L [nm]
no mask	4	–	–, –	$16.64 \cdot 10^{-3}$	$17.44 \cdot 10^{-3}$	5.77
mask (1opt)	4	6	3, 7	$13.20 \cdot 10^{-3}$	$1.972 \cdot 10^{-3}$	2.57
mask (2opt)	4	7.8	2.6, 7.6	$7.921 \cdot 10^{-3}$	$7.400 \cdot 10^{-5}$	1.35
mask (3opt)	4	7.2	1.2, 6.8	$0.742 \cdot 10^{-3}$	$0.123 \cdot 10^{-3}$	0.146
no mask	2	–	–, –	$7.761 \cdot 10^{-3}$	$64.46 \cdot 10^{-3}$	12.2
mask (1opt)	2	3	1.6, 3.6	$3.955 \cdot 10^{-3}$	$21.65 \cdot 10^{-3}$	4.33
mask (2opt)	2	4	1.4, 3.4	$4.842 \cdot 10^{-3}$	$5.708 \cdot 10^{-3}$	1.79

Calculated optical mixing isolation and corresponding maximum displacement error ($\lambda = 1064nm$)

Blocking Masks





beam at fiber output

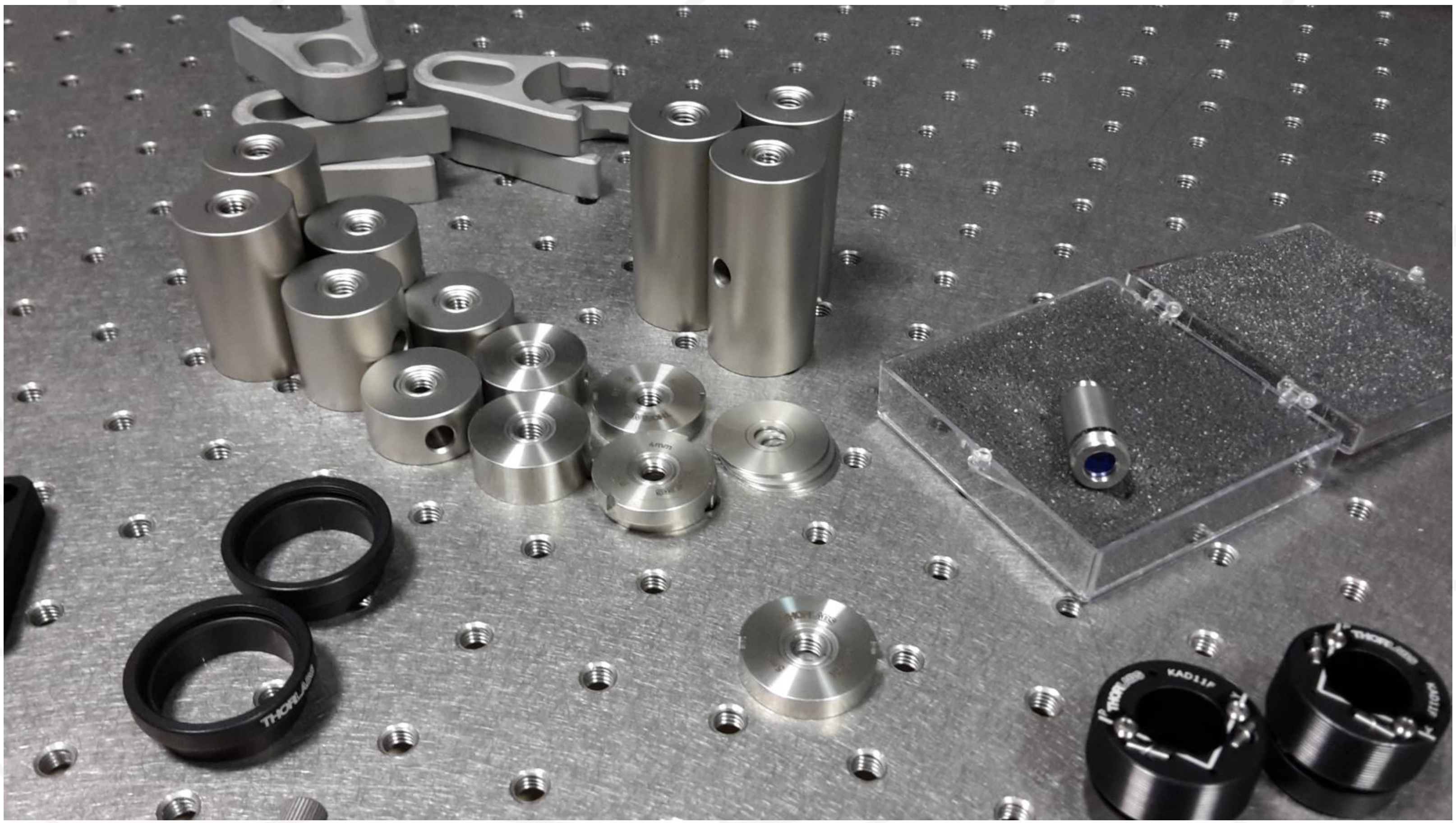
REF beam after masking

RTK beam after masking

beam after recombination

New components

Ø1" Optical Posts → expected lower drift
4mm fiber collimators



Waiting for...

- NI cRIO-9035
- PI E-727 digital piezo controller
- PI P-616 3D cube nano
- Newport Hollow Corner-cube
- Analog mixers


Certificato di Partecipazione

Si certifica che

Alberto Donazzan

ha frequentato e completato con successo nei giorni

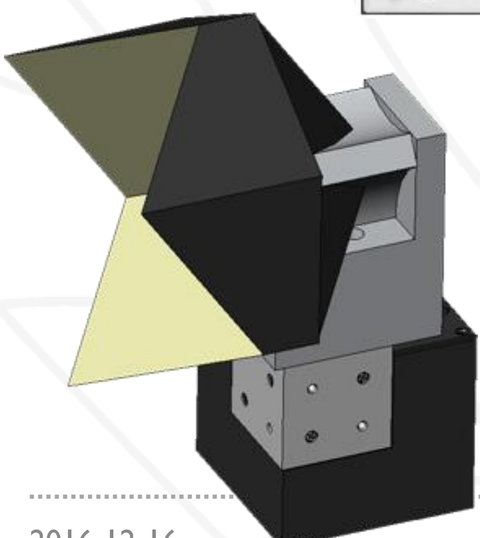
28-29-30 novembre 01-02 dicembre 2016

il programma di addestramento di

Embedded Control and Monitoring in LabVIEW

Istruttore

Luigi Brocchi, Responsabile Formazione
National Instruments Italy Srl



Near future Work

Acquisition & Actuation

- Digital data acquisition
- Gauge test and performance evaluation
- Implementation of a simple feedback loop for single distance stabilization:

Test of the Shape & Pose Decomposition
(Cuccato, Ortolan)

- Dedicated digital phasemeter
- 3-axial piezo-stage
- cRIO GPS module

Optical Upgrade

- Beam shaping for compactness
- Mechanical stability evaluation
- Thermal stability evaluation

- Low-drift mounts
- Reflective fiber collimators
- Hollow corner-cubes
- Optimized drilled mirrors
- Optimized blocking masks

Thank you