



# Current status of GEMS

GINGER meeting  
Padova, 2016-12-16

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

<sup>1</sup> Department of Information Engineering, University of Padova - Padova (Italy)

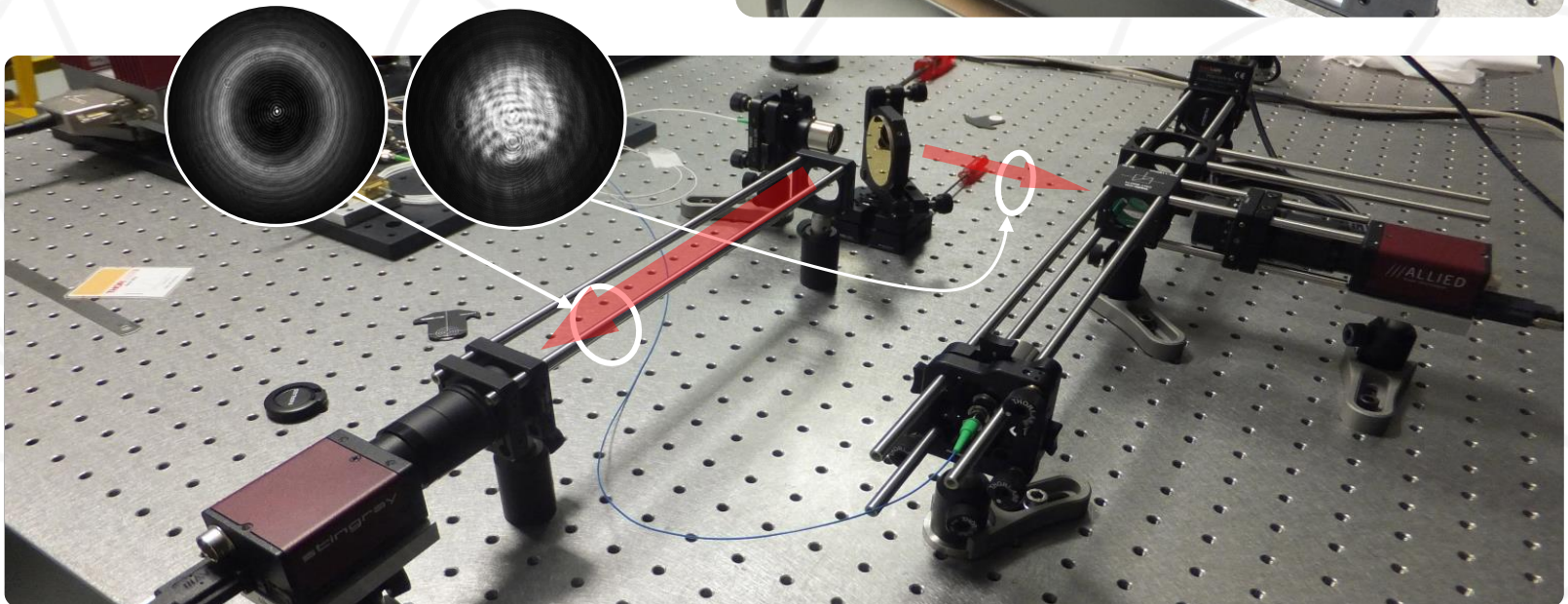
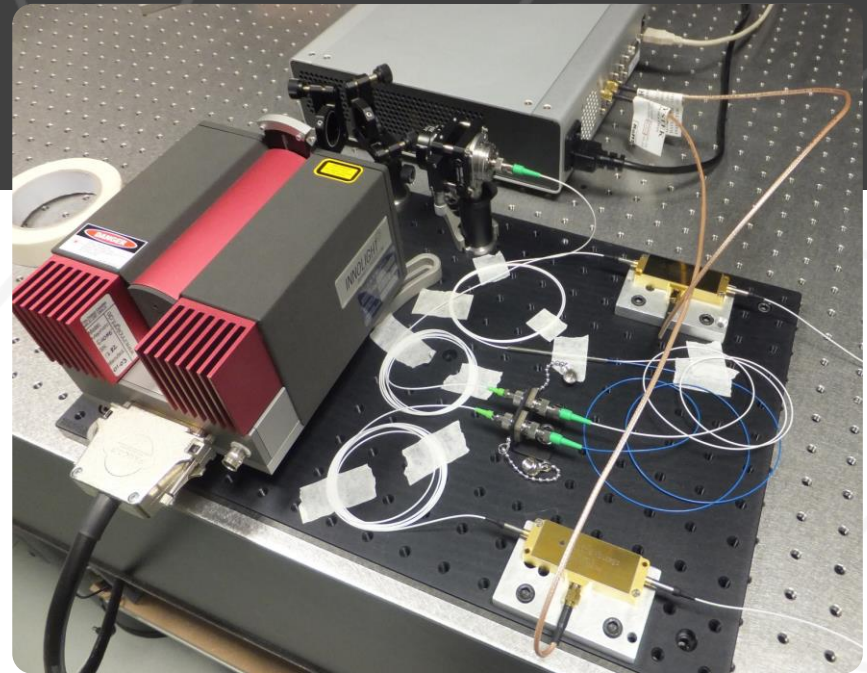
<sup>2</sup> CNR, Institute of Photonics and Nanotechnology - Padova

<sup>3</sup> National Institute for Nuclear Physics - Padova



# Summer Status

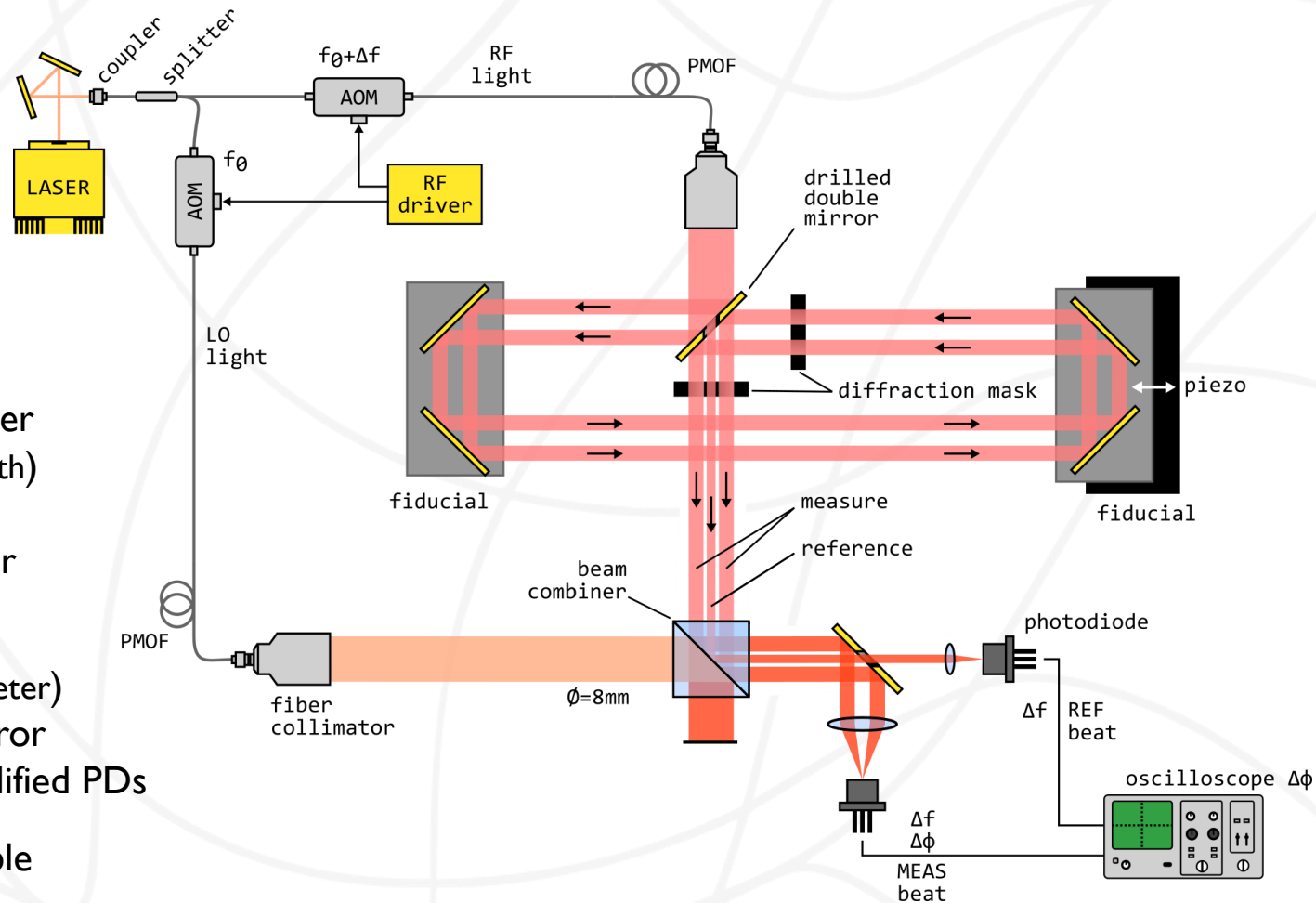
- Heterodyne source aligned and properly working → optical beat with widely tunable  $\Delta f$
- Beam spoiling along racetrack, due to diffraction and poor retro-reflectors.
- Blocking masks are under study



# Prototype layout

## Features

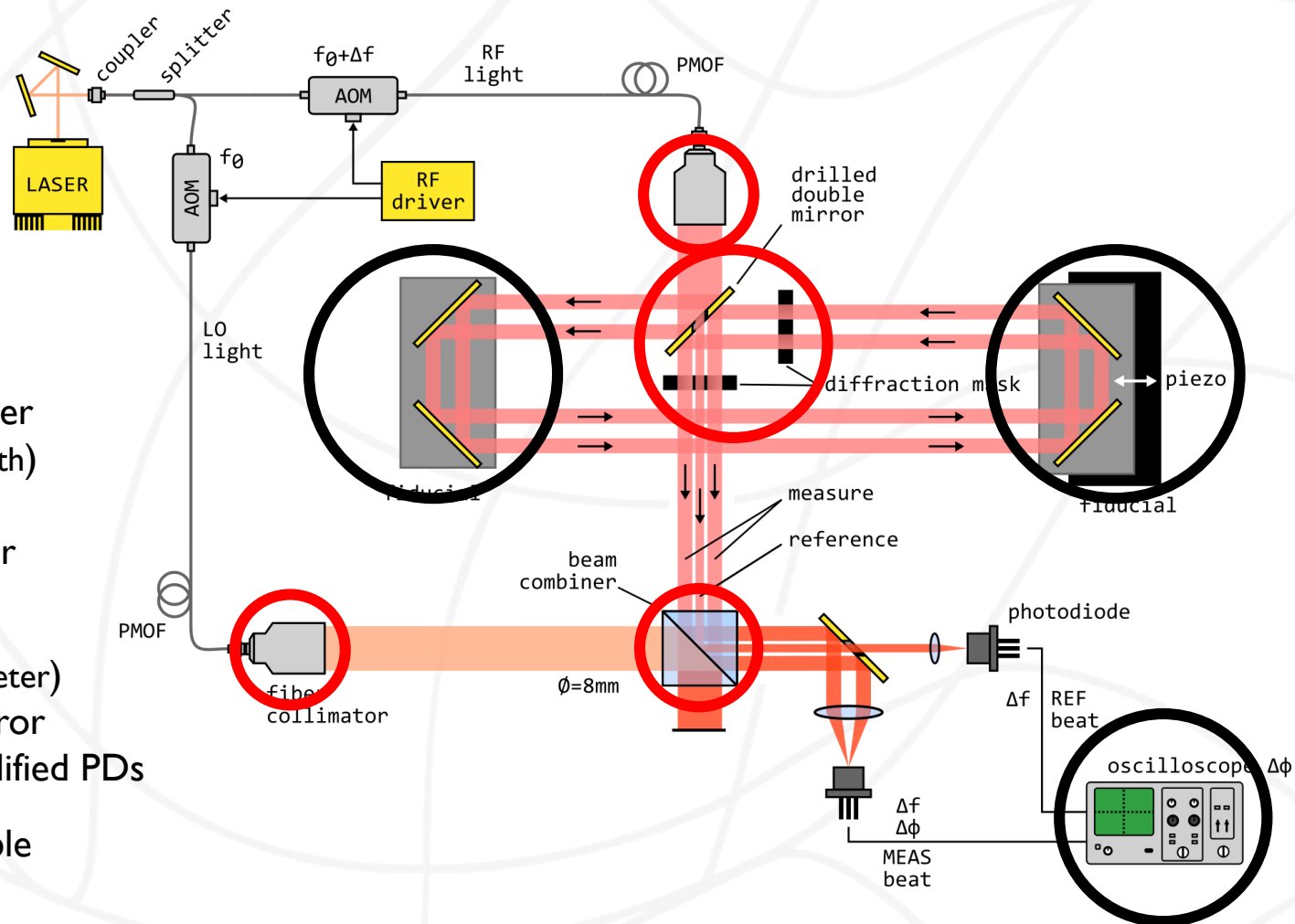
- Nd:YAG DPSS cw laser (1064nm, 1kHz linewidth)
- Fiber AOMs
- FPGA based RF driver
- Fiber collimators (8mm  $1/e^2$  beam diameter)
- 2" drilled double mirror
- Transimpedance amplified PDs
- Vibration isolated table
- Air environment



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# Standard vs Cancelable Circuit

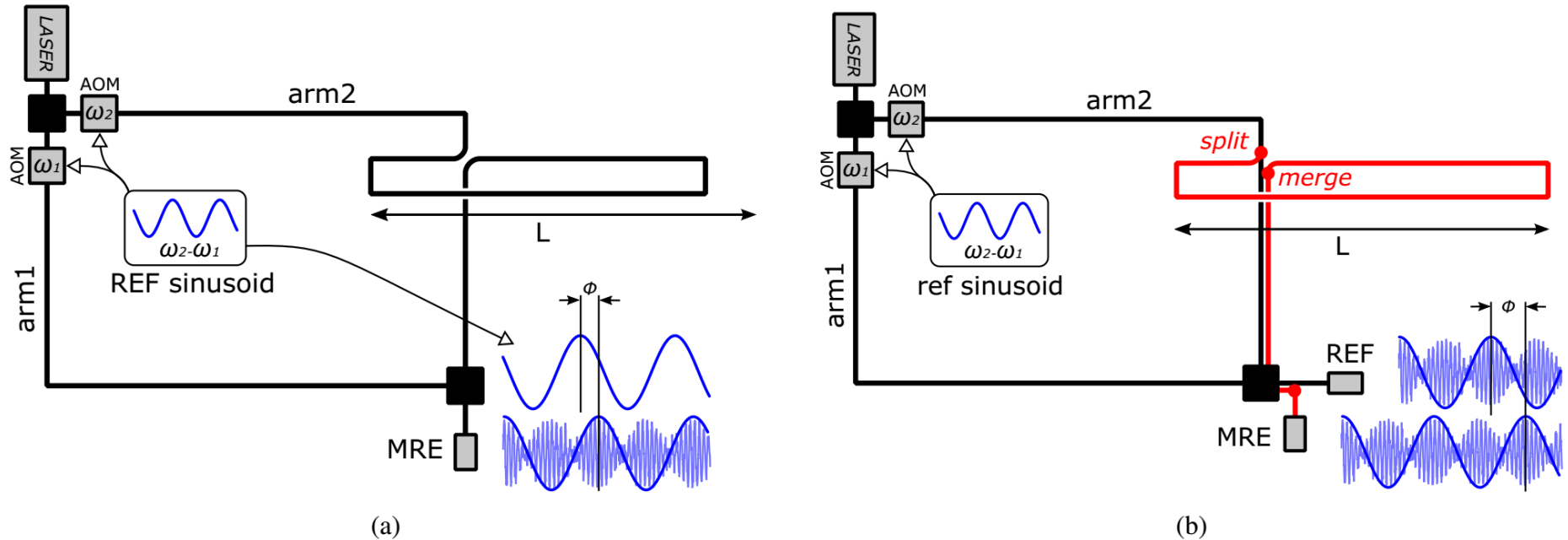


Fig. 1: Simplified optical layout for a displacement heterodyne interferometer placed in between the fiducials defining the concerned distance: (a) standard design and (b) cancelable circuit.

# 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:

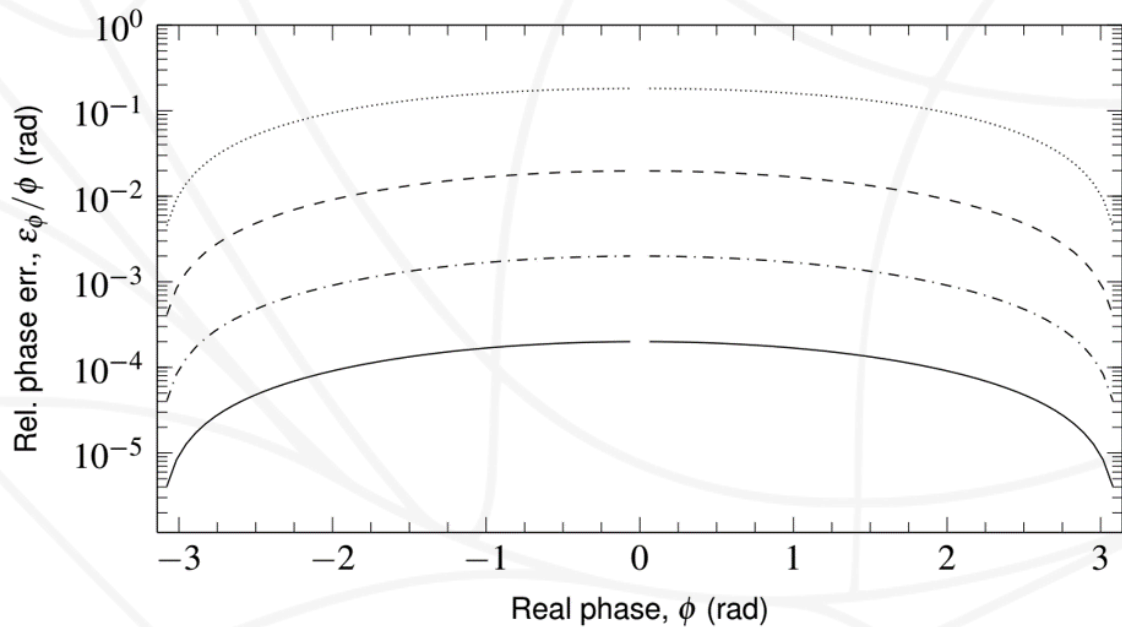
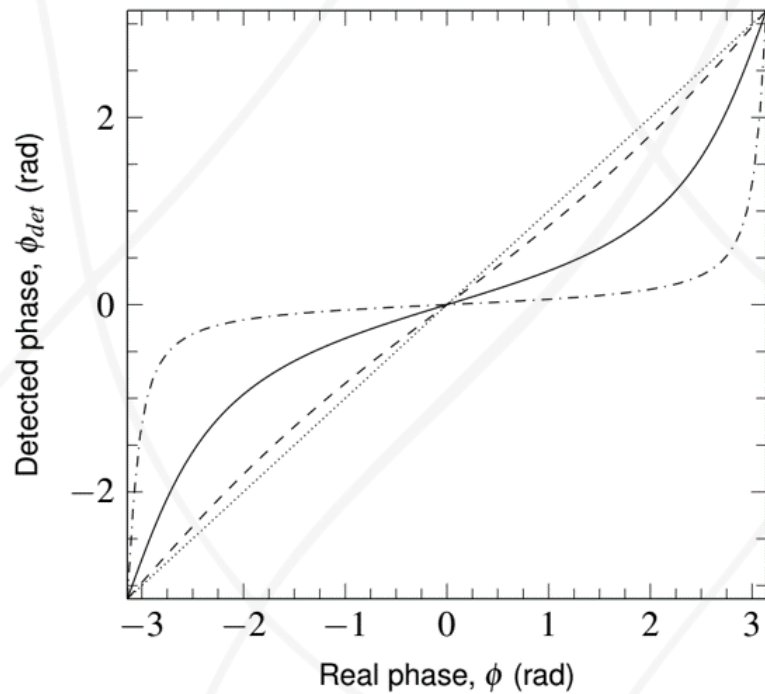
$$\begin{aligned} REF(t) &= R \sin(\omega_2 t) + M_{leak} \sin(\omega_2 t - \phi) \\ MSE(t) &= R_{leak} \sin(\omega_2 t) + M \sin(\omega_2 t - \phi) \end{aligned}$$

$\omega_2$ : optical frequency in arm 2

In the case of zero-crossing phase detection:  $REF(t_R) = 0$   
 $MSE(t_M) = 0$

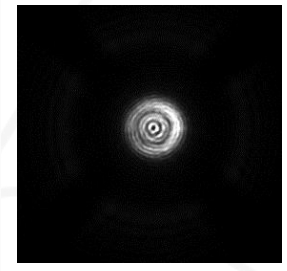
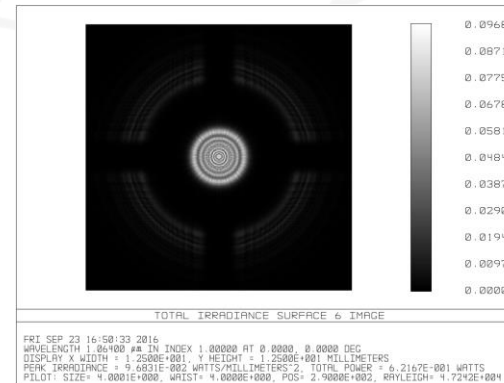
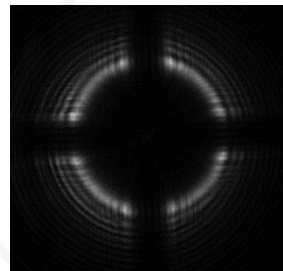
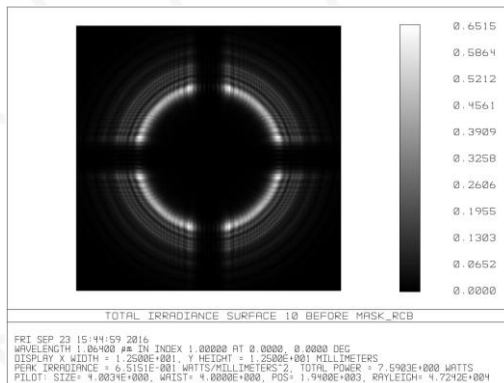
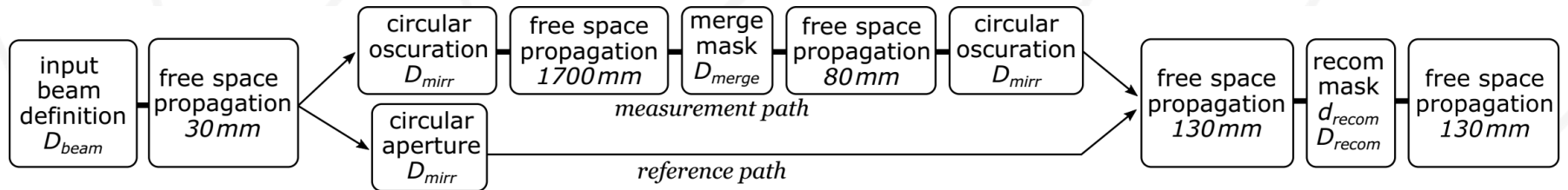
$$\begin{aligned} \phi_{det}(\phi) &= t_M(\phi) - t_R(\phi) \\ &= \arccos\left(\frac{R_{leak} + M \cos(\phi)}{\sqrt{R_{leak}^2 + 2R_{leak}M \cos(\phi) + M^2}}\right) - \arccos\left(\frac{R + M_{leak} \cos(\phi)}{\sqrt{R^2 + 2RM_{leak} \cos(\phi) + M_{leak}^2}}\right) \end{aligned}$$

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



# 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<sup>®</sup> Physical Optics Propagation

	25 BLNK	BLNK/RTK Beam power	Before mask_RCB	INNER								
ZEMAX-EE - 19052 - C:\	26 POPD	POPD	11	1	0	3	0.000000	0.000000	0.000000	0.000000	0.300831	0.000000
File Editors System An	27 POPD	POPD	11	1	0	40	2.000000	0.000000	0.000000	0.000000	0.003362	0.000000

### Lens Data Editor: Config 1/2

Surf	Type	Comment	Radius	Thickness	Glass	Semi-Diameter	Conic
0BJ	Standard		Infinity	Infinity		0.000000	0.000000
*	Standard	from collimator	Infinity	30.000000		20.000000	U
2*	Standard	drill RTK	Infinity	0.000000		5.000000	
3	Standard	RTK	Infinity	1500.000000		5.000000	
4*	Standard	last fold	Infinity	200.000000		12.700000	U
5	Standard	before mask_RTK	Infinity	0.000000		5.000000	
6*	Standard	hold mask_RTK	Infinity	0.000000		5.000000	
7*	Standard	mask_RTK	Infinity	0.000000		5.000000	
8	Standard	mask to mir	Infinity	80.000000		5.000000	
9*	Standard	drill MIRR bk	Infinity	0.000000		5.000000	
10	Standard	common path	Infinity	130.000000		5.000000	
11	Standard	before mask_RCB	Infinity	0.000000		5.000000	
12*	Standard	hold mask_RCB	Infinity	0.000000		5.000000	
13*	Standard	mask_RCB	Infinity	0.000000		2.000000	U
14	Standard	to detectors	Infinity	130.000000		5.000000	

### 1: Physical Optics Propagation 1

### 5: Physical Optics Propagation 5

### Multi-Configuration Editor

Active	1/2	Config 1*	Config 2
1:	IGNR	3	0
2:	IGNR	5	0
3:	IGNR	6	0
4:	IGNR	7	0
5:	IGNR	8	0

### 6: Physical Optics Propagation 6

### 2: Physical Optics Propagation 2

### 3: Physical Optics Propagation 3

### 4: Physical Optics Propagation 4

### 7: Physical Optics Propagation 7

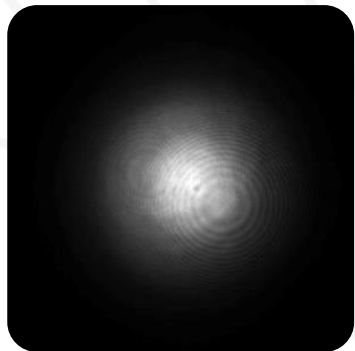
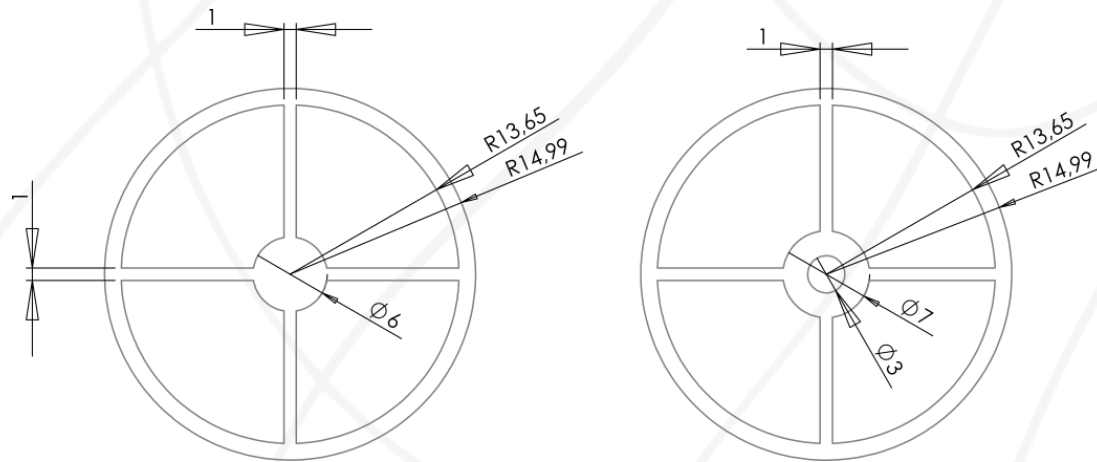
EFFL: 1e+010      WFNO: 1000      ENPD: 10      TOTR: 2070

# Simulation results

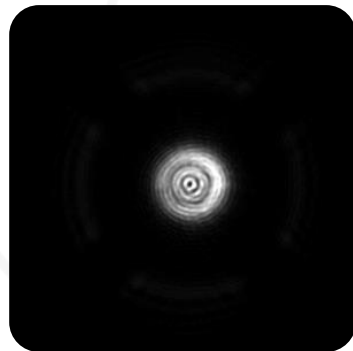
Configuration	$D_{\text{mirr}}$ [mm]	$D_{\text{merge}}$ [mm]	$d_{\text{recom}}, D_{\text{recom}}$ [mm]	$R_{\text{leak}} / M$	$M_{\text{leak}} / R$	$\epsilon_L$ [nm]
no mask	4	–	–, –	$16.64 \cdot 10^{-3}$	$17.44 \cdot 10^{-3}$	5.77
mask (1opt)	4	6	3, 7	$13.20 \cdot 10^{-3}$	$1.972 \cdot 10^{-3}$	2.57
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 ( $\lambda = 1064\text{nm}$ )

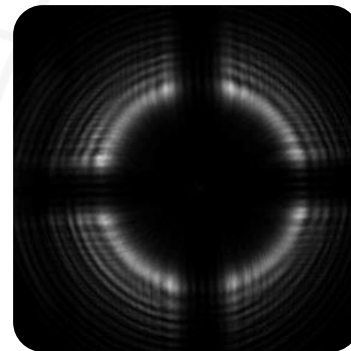
# Blocking Masks



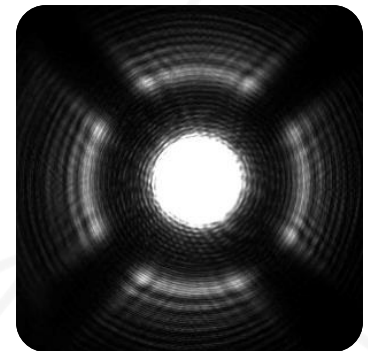
beam at fiber  
output



REF beam  
after masking



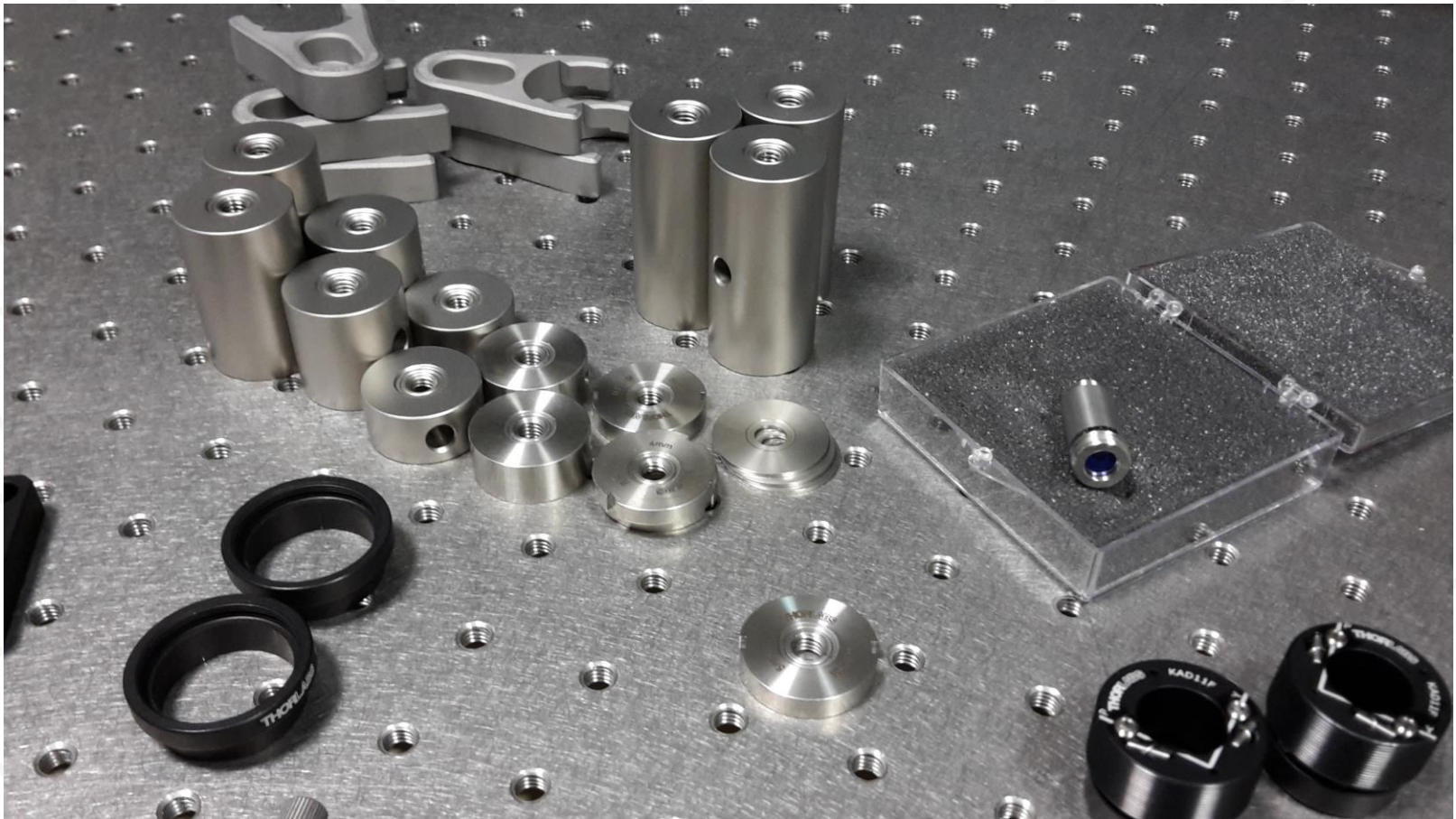
RTK beam  
after masking



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

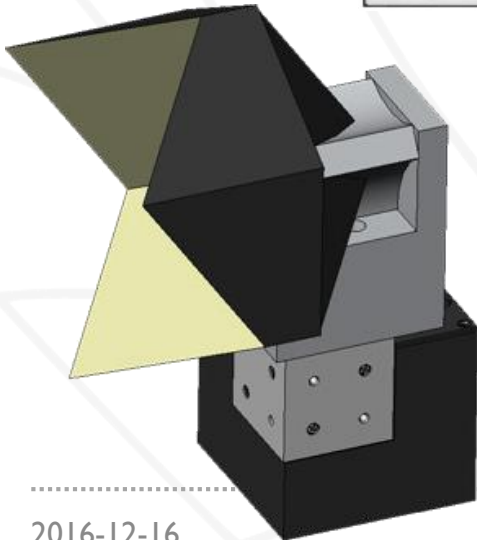
28-29-30 novembre 01-02 dicembre 2016

il programma di addestramento di

**Embedded Control and Monitoring in LabVIEW**

Istruttore  
*Luigi Brocchi*

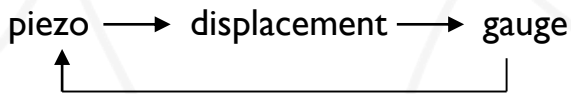
Luigi Brocchi, Responsabile Formazione  
National Instruments Italy Srl



# 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

