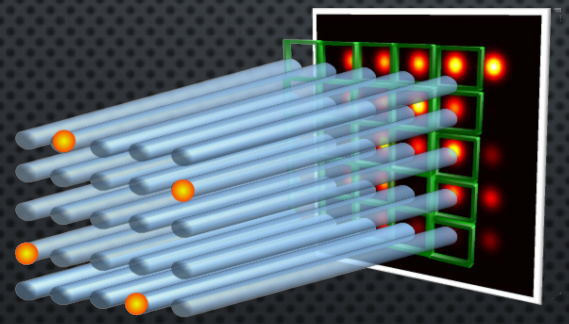
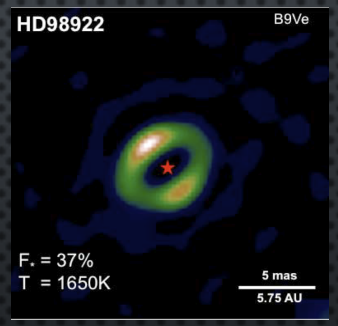
INTEGRATED OPTICS INTERFEROMETRY ACTIVITIES IN POTSDAM AND JENA





STEFANO MINARDI, ETTORE PEDRETTI, ROMINA DIENER, ABANI SHANKAR NAYAK

innoFSPEC
Innovative faseroptische Spektroskopie und Sensorik

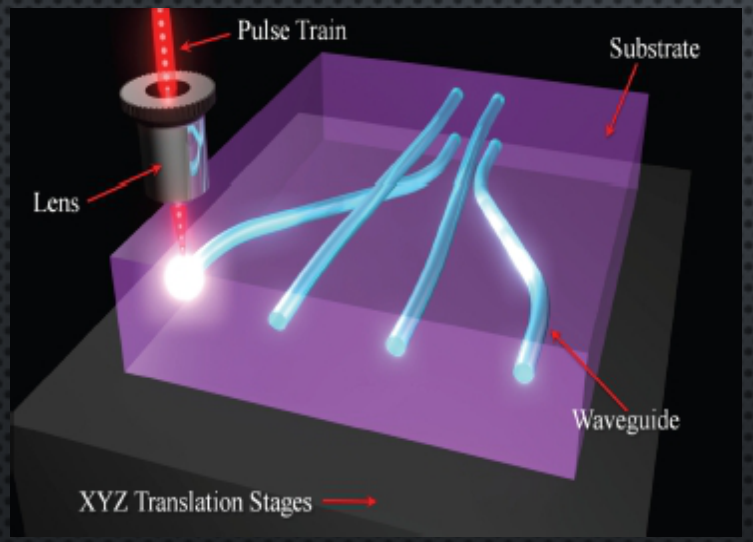
AIP
Leibniz-Institut für Astrophysik Potsdam

seit 1558

Interferometry projects Jena/Potsdam

- **ALSI** (Advanced Laser Writing for Stellar Interferometry) 2014-2017, Jena
- **IA** (Integrated astrophotonics) 2016-2021, Potsdam.
- **NAIR** (Novel Astronomical Instrumentation based on Photonic Light Reformatting) 2017-2020, Potsdam (Jena)

ALSI PROJECT



Ultrafast laser inscription (ULI)

Collaborative project Jena-Cologne (2014-2017)

Jena contribution:

- Development of ULI in GLS.
- Fabrication of samples.
- Test components in monochromatic MIR light.

After December 2017:

- Jena: Fabrication on dedicated ULI setup.
- Potsdam: test of DBC components.

Romina Diener

IA PROJECT

ASTROCOMBS

DR. JOSE CHAVEZ BOGGIO

DANIEL BODENMÜLLER

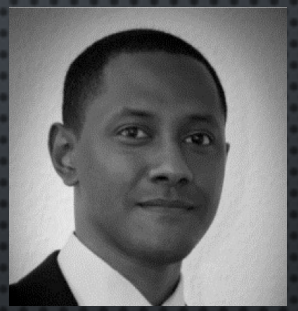
- GENERATE NIR ASTROCOMBS IN SIN MICRO-RING RESONATORS FOR R>20000 SPECTROGRAPHS.
- DEVELOP AND TEST CALIBRATOR ON-SKY.

SPECTRO-INTERFEROMETRY

DR. ETTORE PEDRETTI

- DESIGN AND TEST BEAM COMBINERS FOR NIR STELLAR INTERFEROMETRY.
- DEVELOP AND TEST COMBINER ON-SKY.

AO/PHOTONIC LANTERNS



MOMEN DIAB

- DESIGN AND TEST PHOTONIC LANTERNS AND AO SYSTEMS.
- DEVELOP AND TEST INTEGRATED SPECTROMETER ON SKY.

NAIR PROJECT

Collaborative project Potsdam-Cologne-Heidelberg-Jena (2017-2020)

Goal: test pupil remapping with multi-aperture combiners
[Minardi, Labadie, Lacour SPIE 2012].

Potsdam contribution:

- Design&characterisation of H-band reformatters/beam combiners.
- Assembly hardware for on-sky test.

Abani Shankar Nayak

POTENTIAL SCIENCE CASES

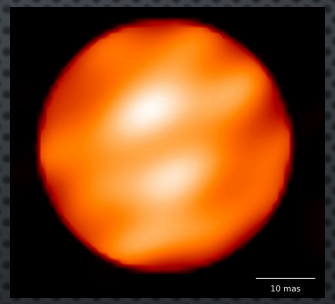
AIP HAS TWO BRANCHES INVESTIGATING **STELLAR PHYSICS** AND **GALACTIC ARCHEOLOGY.**

STELLAR PHYSICS:
- RESOLVE FEATURES ON STELLAR SURFACES (J/H).
- CHEMICAL SPOTS ON MAGNETIC STARS (J/H).

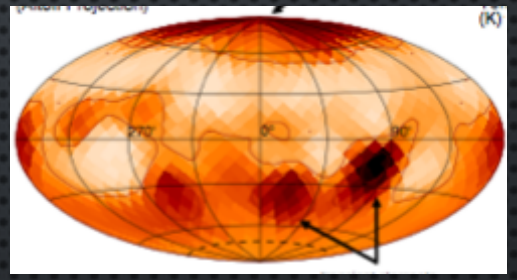
STELLAR ENVIRONMENTS:
- PROTOPLANETARY DISKS (L/M).

AGN:
- IMAGES OF DUST TORI (J/H/K/L/M).

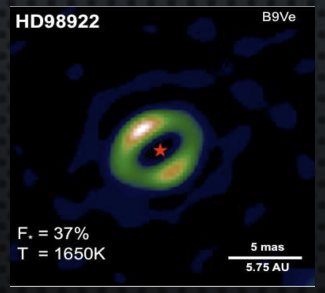
GALACTIC ARCHEOLOGY:
- STAR DIAMETERS (J/H).



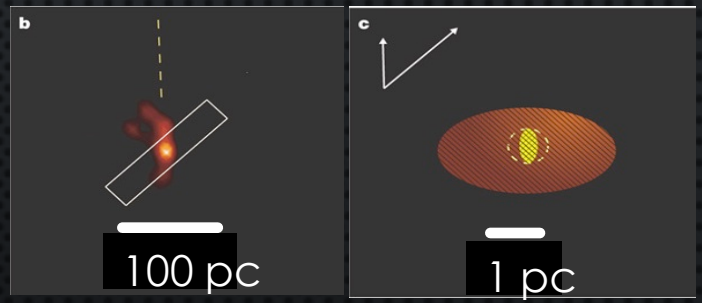
[Haubois 2009]



[Röttenbacher 2016]

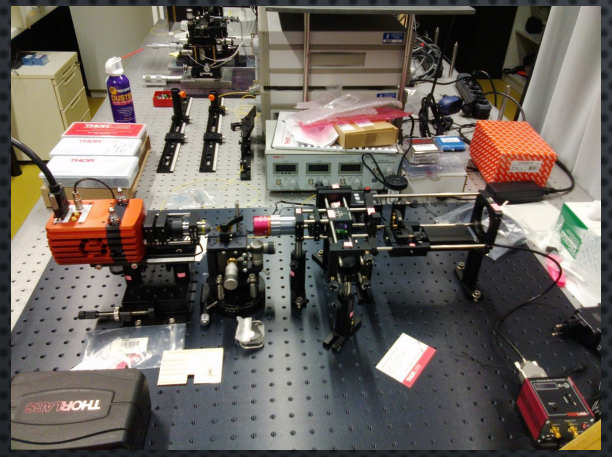


[Kluska 2014]

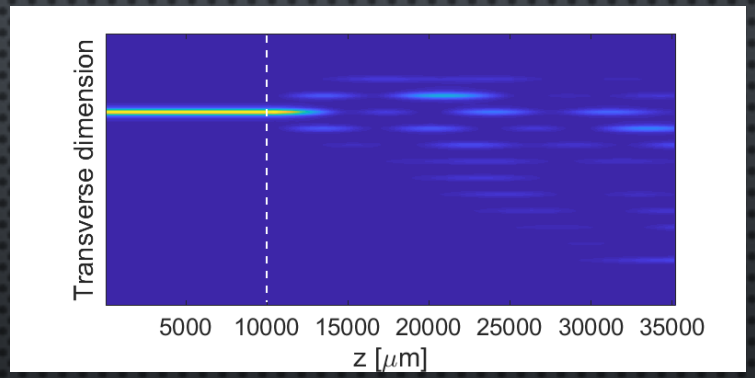


[Wittkowski et al. 2004]

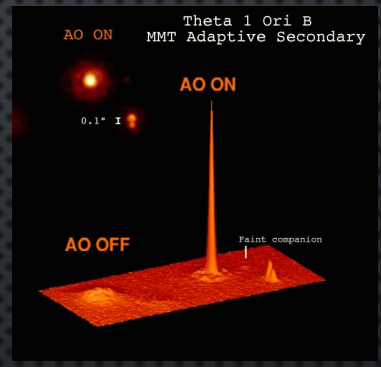
AVAILABLE/PLANNED FACILITIES IN POTSDAM



- NIR INTERFEROMETRIC TESTBENCH.
- LASER AND CONTINUUM SOURCES.
- 100/400 HZ COOLED INGAAS CAMERA.
- 60 HZ INSB CAMERA.
- UPGRADE TO >6 CHANNELS PLANNED.

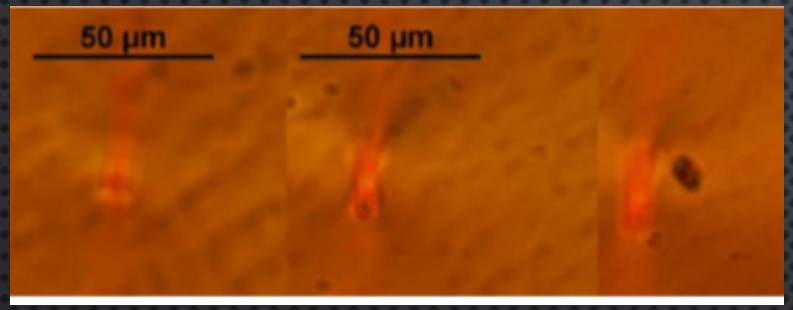


- NUMERICAL SIMULATION TOOLS.



- SCAO SETUP.
- CRYOGENIC CHAMBER.

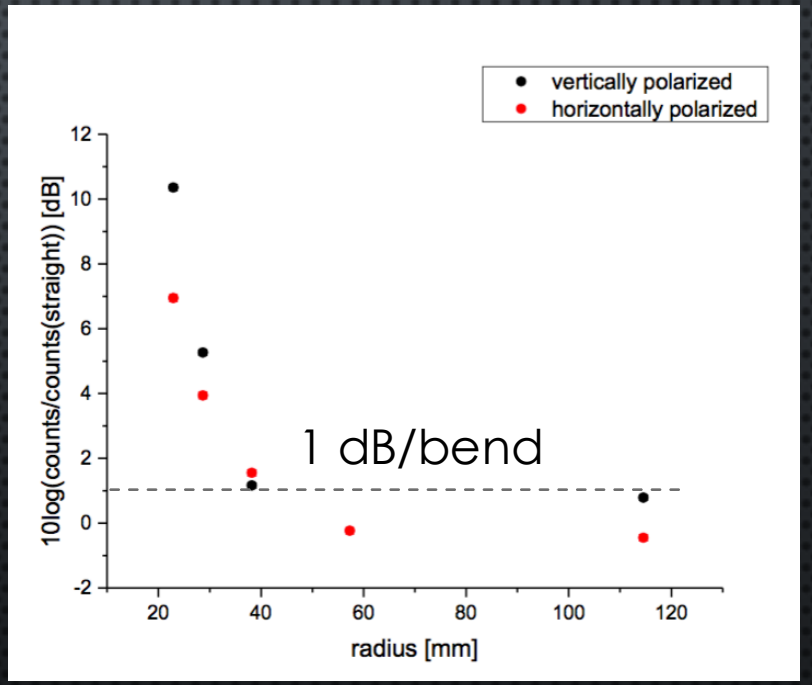
ULI WAVEGUIDES IN GLS



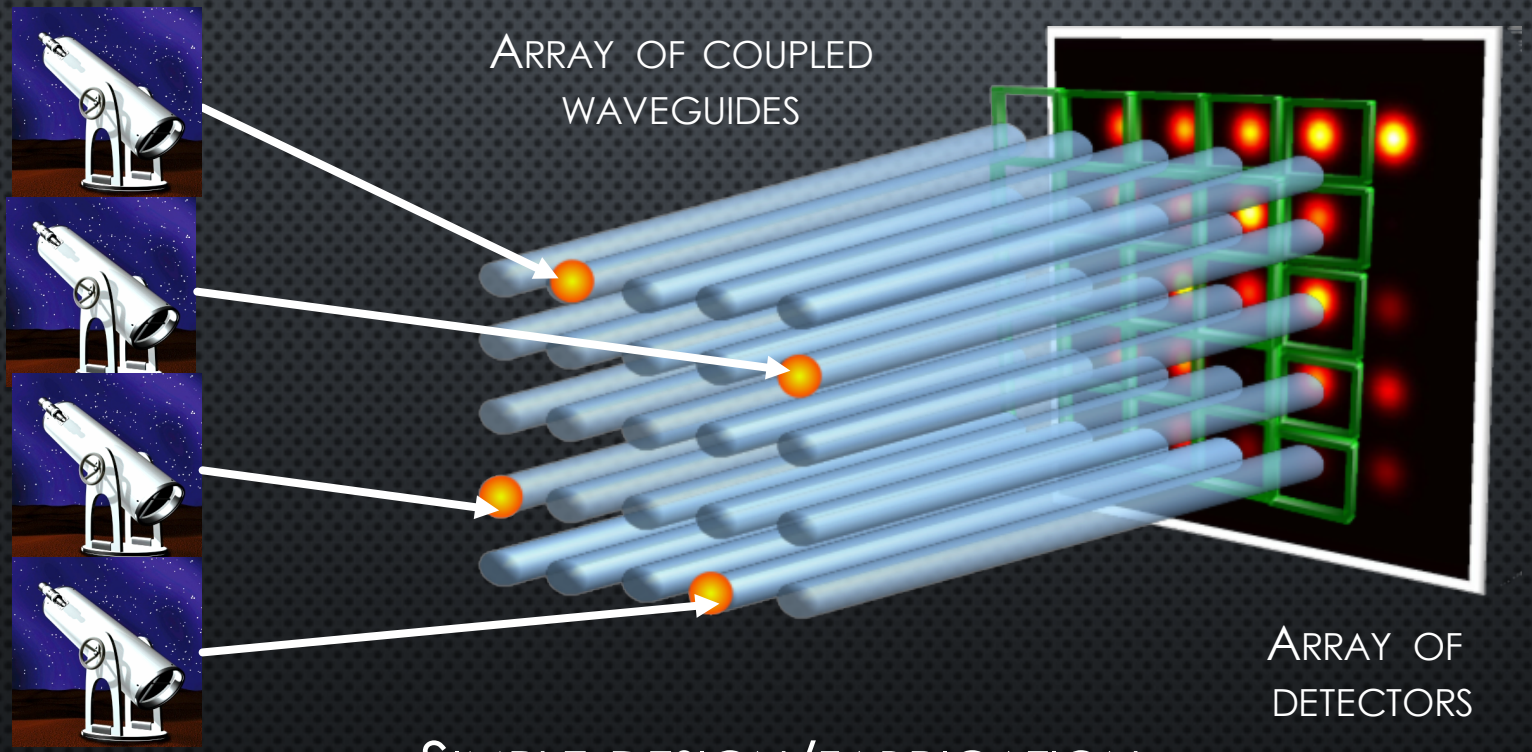
PEAK INDEX CONTRAST ~$5 \cdot 10^{-3}$

PROPAGATION LOSS 0.9+/-0.2 dB/cm

BEND LOSS <1dB/BEND FOR R>40 mm

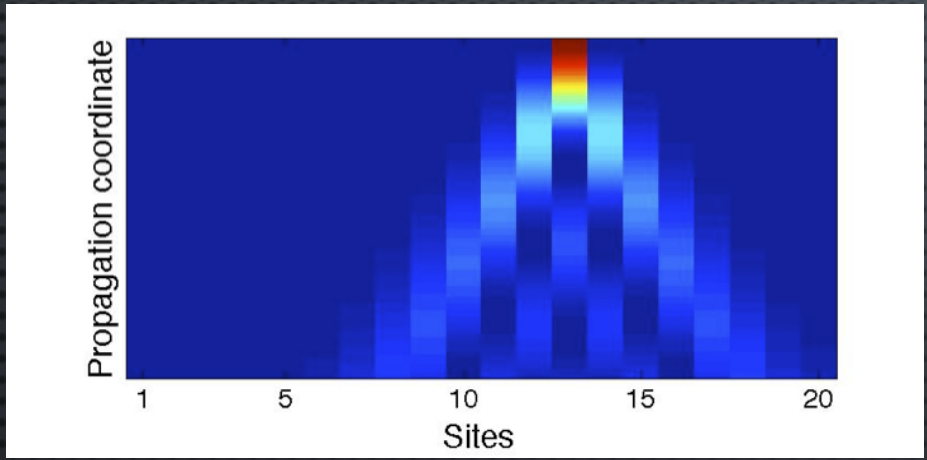


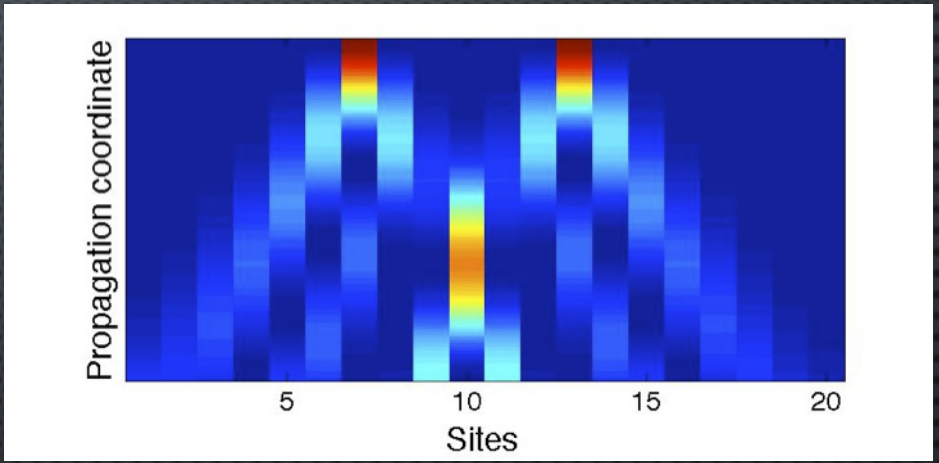
THE DISCRETE BEAM COMBINER



- SIMPLE DESIGN/FABRICATION. ✔
- SCALABLE TO LARGE NUMBER OF TELESCOPES. ✔
- RATHER CHROMATIC. ✘

HOW DO DBC WORK





SINGLE WAVEGUIDE EXCITATION

TWO WAVEGUIDE EXCITATION

V2PM DESCRIPTION OF SYSTEM:

$$I_n = \sum_{i=1}^{N^2} \alpha_{ni} J_i$$

$$\vec{J} = \left(\langle |A_1|^2 \rangle \ldots \langle |A_N|^2 \rangle \langle A_1 A_2^* \rangle \ldots \langle A_1 A_N^* \rangle \ldots \langle A_{N-1} A_N^* \rangle \right)^T$$

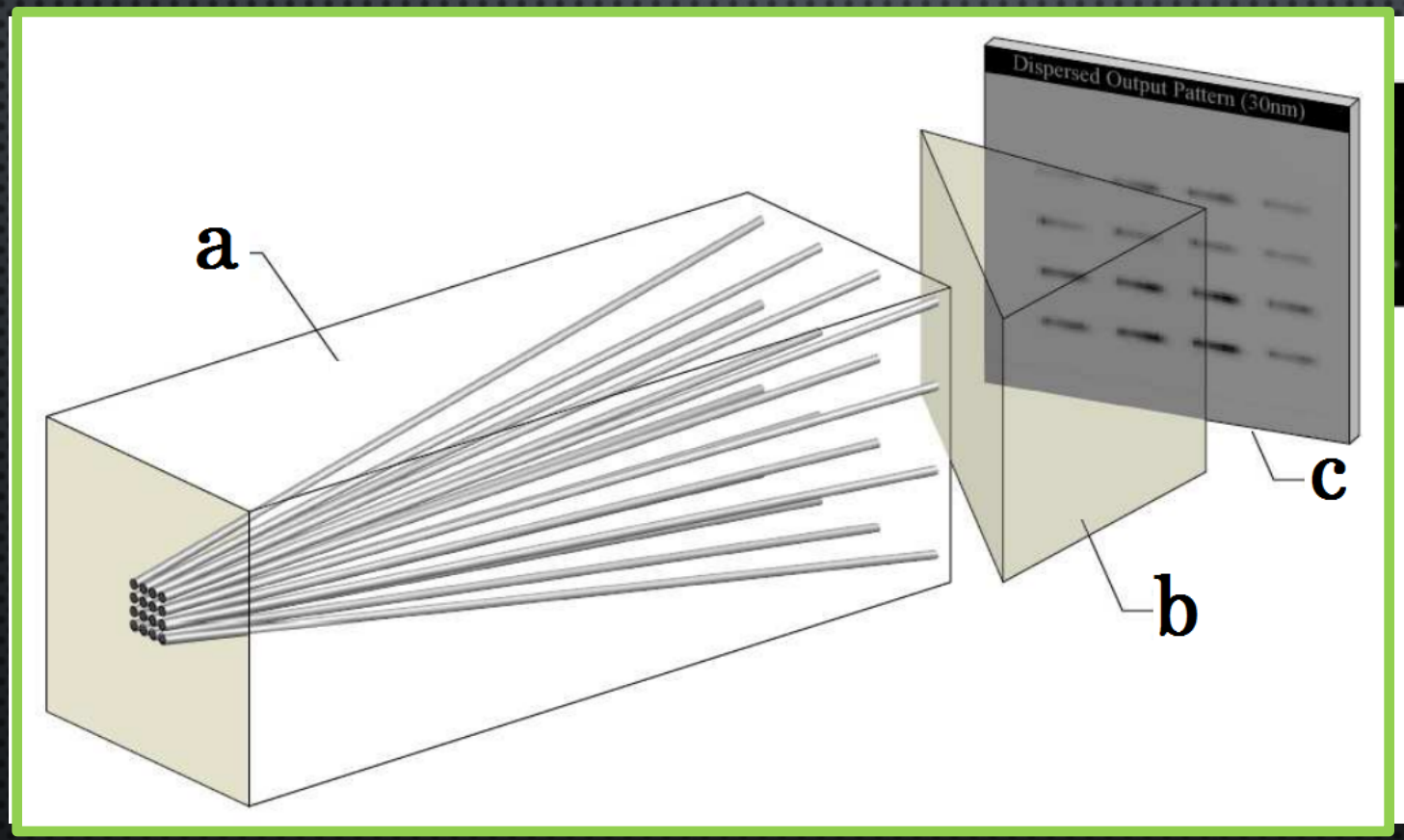
[MINARDI, PERTSCH *Opt. Lett.* **35,** 3009 (2010), MINARDI *MNRAS* **422**, 2656 (2012).]

Accuracy of coherence retrieval

$$\{\alpha_{ni}\}$$

- (pseudo)-inversion of $\{\alpha_{NI}\}$ is possible if $N_{WG}>N^2$
- The matrix should be well conditioned.
- Conditioning depends on input sites and array length.

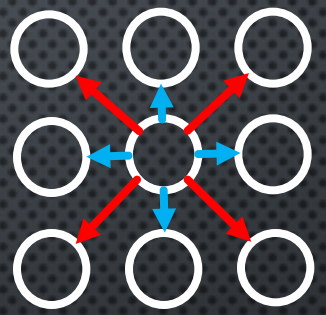
POLYCHROMATIC OPERATION

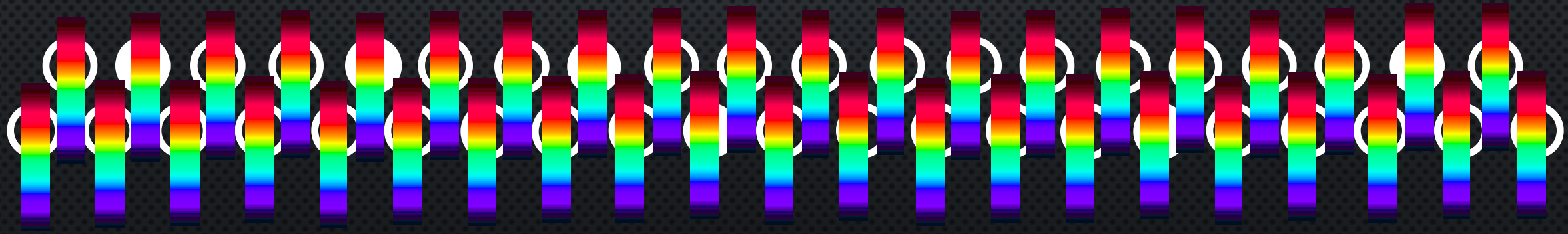


[Saviauk et al. Appl. Opt. **52**, 4556 (2013)]

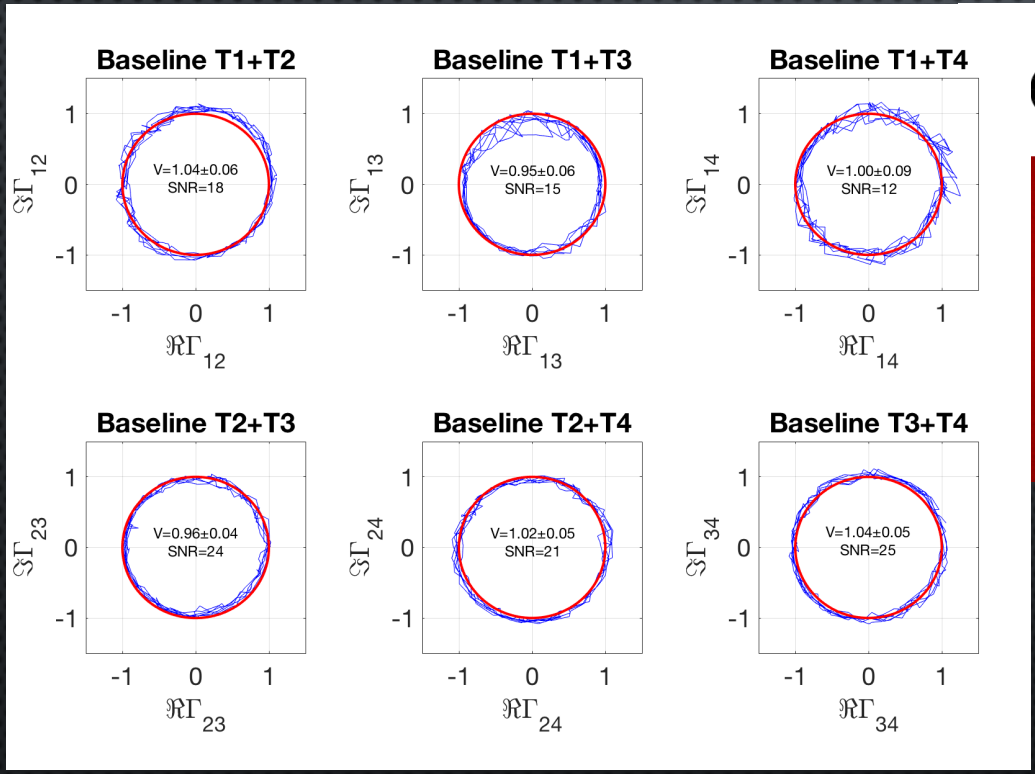
ZIG-ZAG DBC

Next-Nearest-Neighbor coupling is a sufficient condition for using arrays of waveguides as combiners.
[Minardi Phys Rev. A **92**, 013804 (2015)]

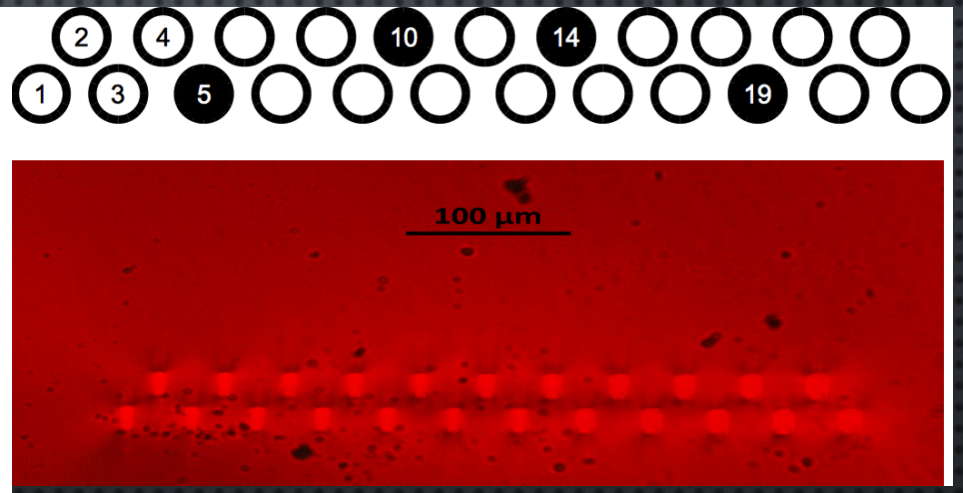




FIRST EXPERIMENTAL RESULTS WITH ZIG-ZAG



[Diener et al. Opt. Exp. **25**, 19262 (2017)]

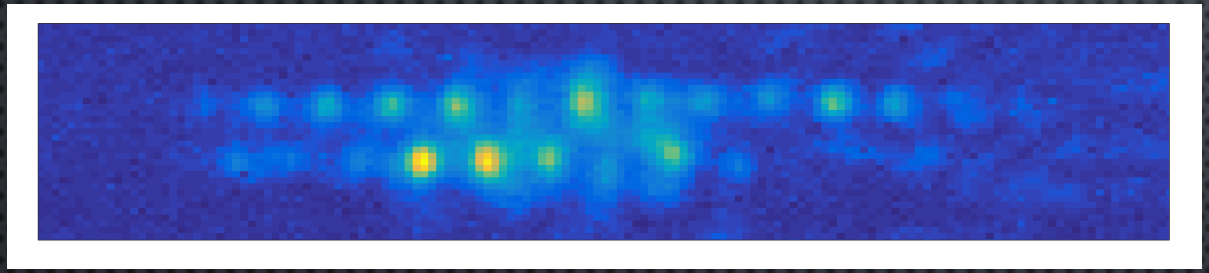


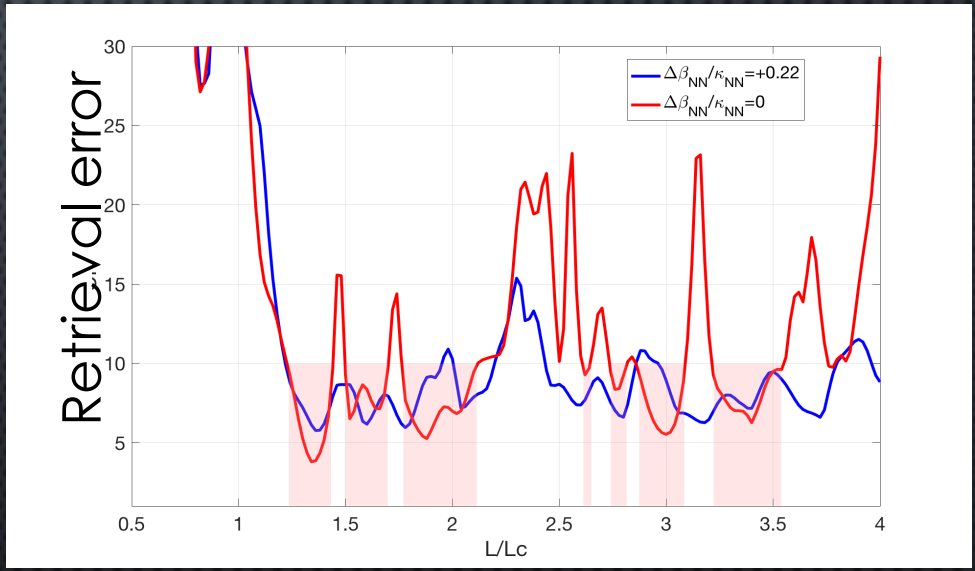
OPERATING WAVELENGTH IN MIR (3.39 µm)

RETRIEVAL OF FRINGES WITH HIGH SNR WITH ~2000 COUNTS PER FRAME.

TOTAL LENGTH: 30 mm ~2.7 dB loss

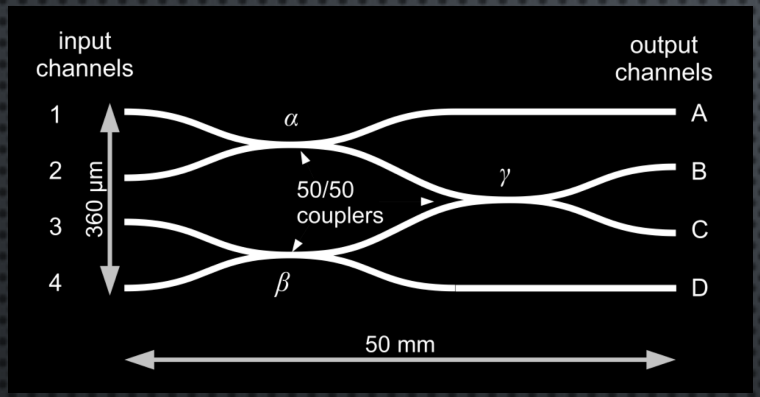
6T ZIG-ZAG AND COMPENSATION OF CHROMATISM



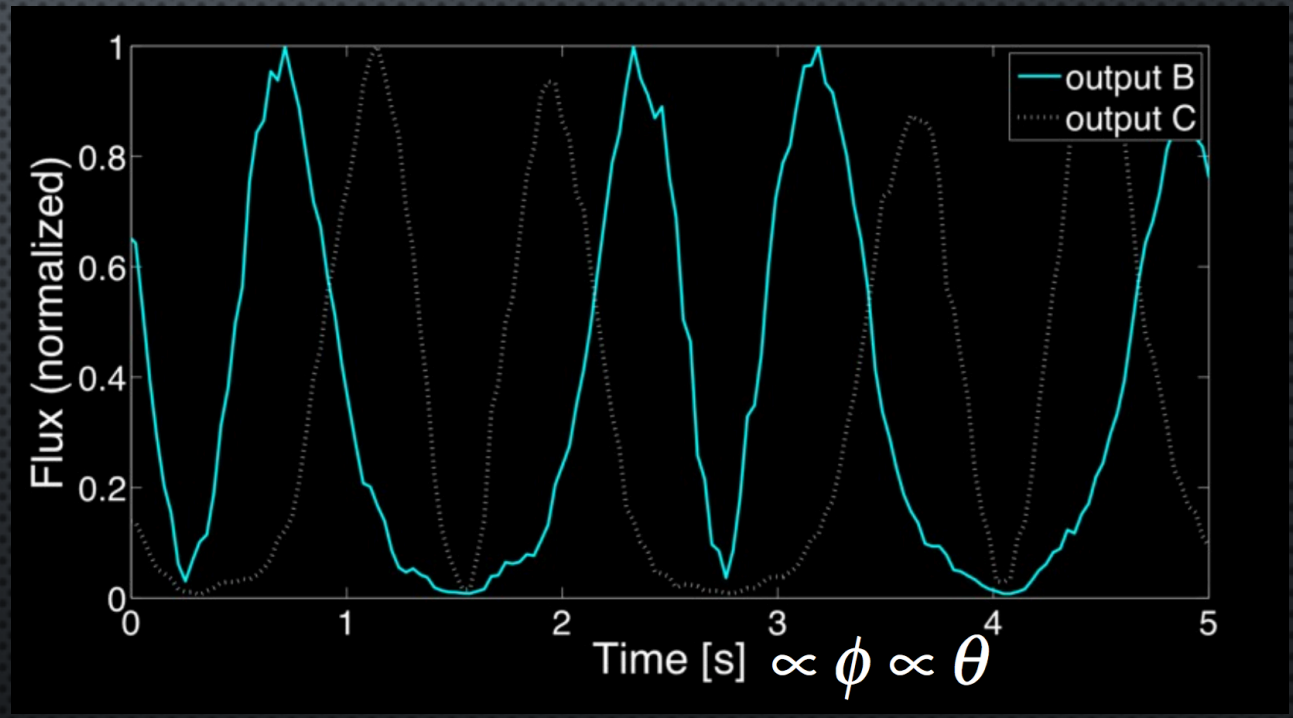


- Currently testing prototypes of 6T DBC for H-band.
- J-band combiners under development.
- Investigation on impact of asymmetries on bandwidth of combination.

4T NULLING CHIP



- PHOTONIC ANGEL/WOLF 4T NULLING SCHEME.
- FLAT NULLING AT THE CAMERA NOISE LEVEL DEMONSTRATED.
- VIS BAND BUT SCALABLE TO MIR.



[Errmann et al. Appl. Opt. **54**, 7449 (2015)]

CONCLUSIONS

- Imaging beam combiners with straight waveguides tested in MIR.
- Investigation of methods for compensation of chromatism going on.
- Committed to on-sky test of astrophotonic technologies.
- Open to collaborations.