Francois Roddier: A Story of Interferometer and Interpersonal Connections

Stuart Shaklan

Graduate Student of Francois at NOAO,
1985-1988

La Tourbillon de la Vie

Paris, June 6, 2025

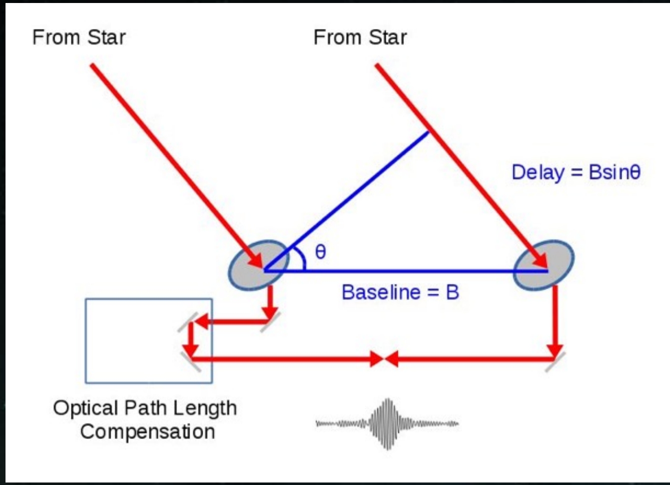
Disclaimer

This is not a detailed description of Francois's many contributions to the field of Long Baseline Interferometry – Pierre Lena, Antoine Labeyrie, and a few others are much better equipped to give such a presentation.

My presentation is a view of what Francois was up to as he turned his focus to long baseline optical interferometry, how his strategic thinking and professional connections led to the first implementation of fiber optics in the field, and how that blazed the path for the use of today's modern photonics devices.

I had the great fortune of working with Francois during this time, and to meet his many colleagues, many of whom are in attendance today.

Long Baseline Interferometry for the Non-Expert

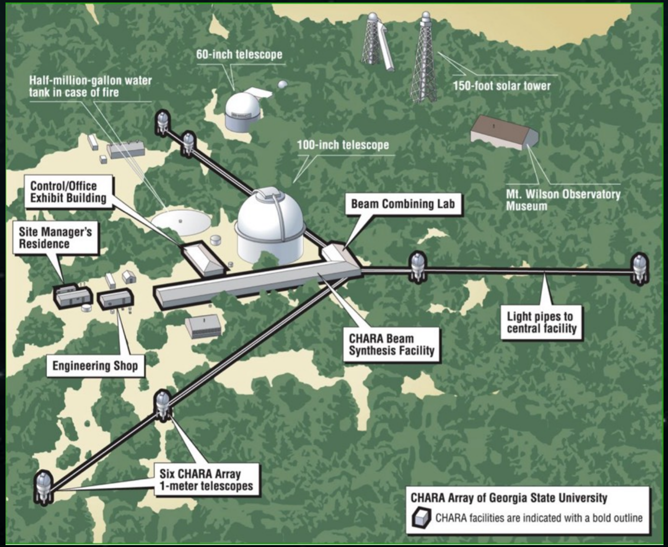


Credit: www.chara.gsu.edu

GI2T, Calern Plateau

Very Large Telescope Interferometer, Chile

Navy Precision Optical Interferometer (NPOI) , Flagstaff, AZ



CHARA Interferometer, Mt. Wilson CA

CHARA Interferometer, Mt. Wilson CA

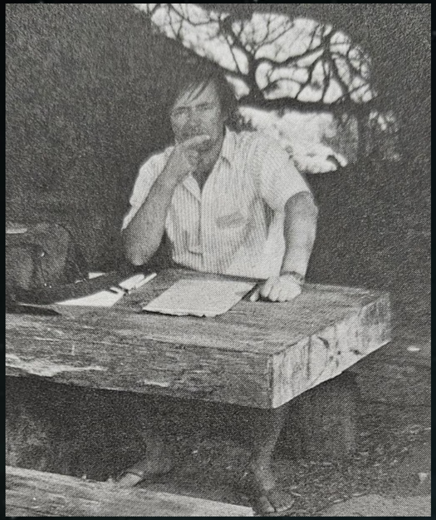
Selected papers by Francois: Understanding and Explaining Turbulence Effects in Astronomical Imaging

Year	Title	Journal or Conference
1974	Speckle interferometry through small multiple apertures. Michelson stellar interferometer and aperture synthesis in optics	Opt. Comm.
1976	Defocusing effects in astronomical speckle interferometry	Optics Comm.
1976	Effects of atmosphere in stellar speckle interferometry (with Claude Roddier)	JOSA
1978	A rotation shearing interferometer with phase-compensated roof-prisms (with Claude Roddier and J. Demarcq)	J. Opt.
1979	Effects of atmospheric turbulence on the formation of visible and infrared images	J. Opt.
1980	New trends in speckle interferometry	Proc. SPIE
1981	*The effects of atmospheric turbulence in optical astronomy*	*Progress in Optics*
1982	On the isoplanatic patch size in stellar speckle interferometry	J. Opt.
1982	On the origin of speckle boiling and its effects in stellar speckle interferometry (with J. M. Gilli and G. Lund)	J. Opt.

Selected papers by Francois: Architectures and Strategies for Long Baseline Interferometry

Year	Title	Journal or Conference
1983	How to achieve diffraction limited resolution with large space telescopes	Advances in Space Research
1983	Future possibilities of ground-based interferometry in the visible (Cargese)	Workshop on ESO's Very Large Telescope
1984	Long Baseline Michelson Interferometry with large ground-based telescopes operating at optical wavelengths…. I. and II. (with Pierre Lena)	Journal of Optics
1985	Mechanical Vibration Constraints on a Long Baseline Michelson Interferometer	NOAO R&D Note
1986	Pupil plane vs. image plane in Michelson stellar interferometry	JOSAA
1987	Imaging strategies for a space-borne interferometer	ESA Workshop on Optical Interferometry in Space (Granada)
1987	Redundant vs. nonredundant beam recombination in an aperture synthesis with coherent optical arrays	JOSAA
1987	Signal to Noise Ratios and Beam Combination	ESO-NOAO Joint Workshop, Oracle AZ
1988	Passive vs. Active Methods in Optical Interferometry	ESO Conference Workshop No. 29

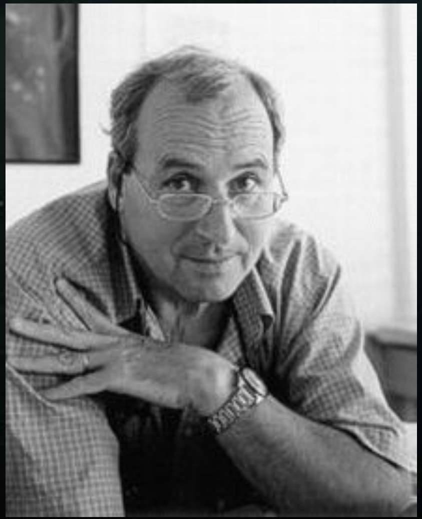
Origins of Fiber Linked Interferometers



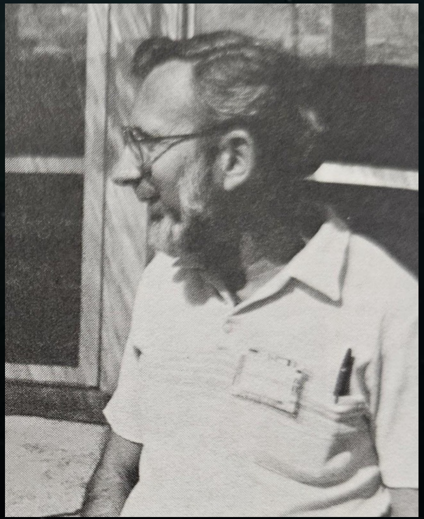
Antoine Labeyrie, Cargese 1988

Three men on a boat, a story told to me by Francois.

Antoine Labeyrie, Francois Roddier, and Claude Froehly sailed from Cannes to Corsica on Labeyrie's boat in 1980. Labeyrie proposed using fiber optics to replace conventional optics in an interferometer beam combiner. Froehly thought through the problem while navigating all night.



Claude Froehly, Limoges (date unknown)



Francois Roddier, Cargese 1988

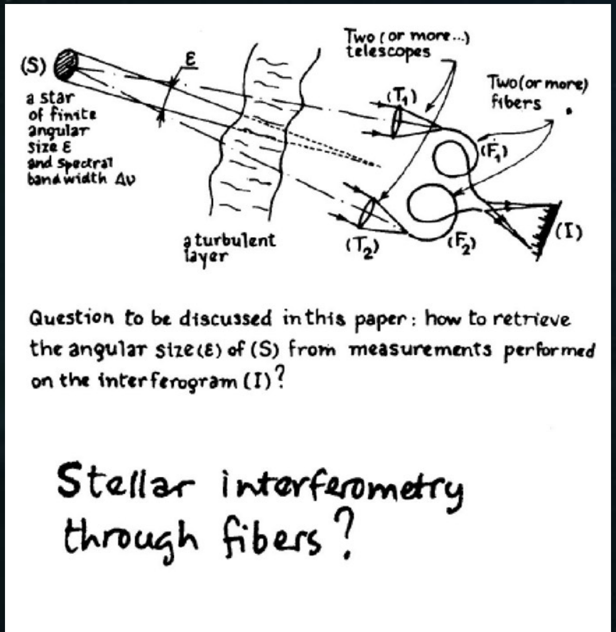


Figure 1

Froehly, ESO Conf. at Garching, 1981

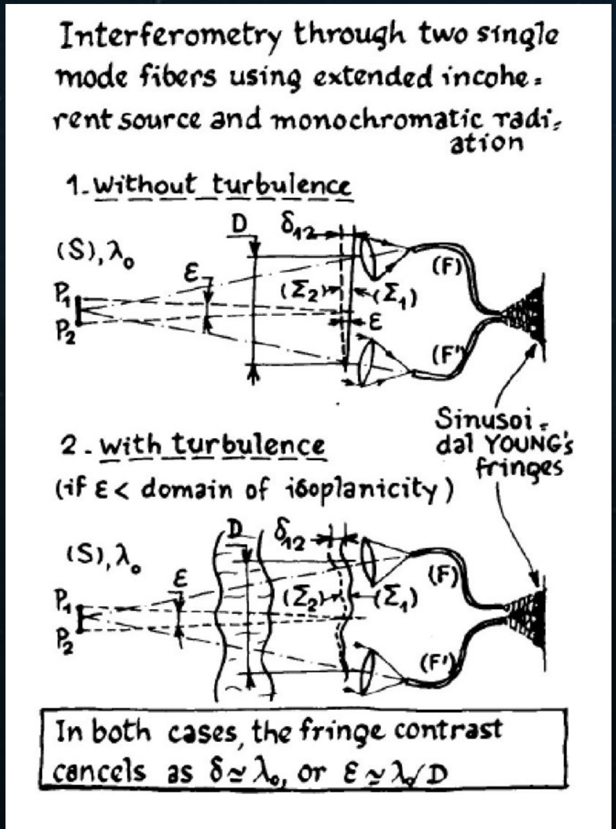
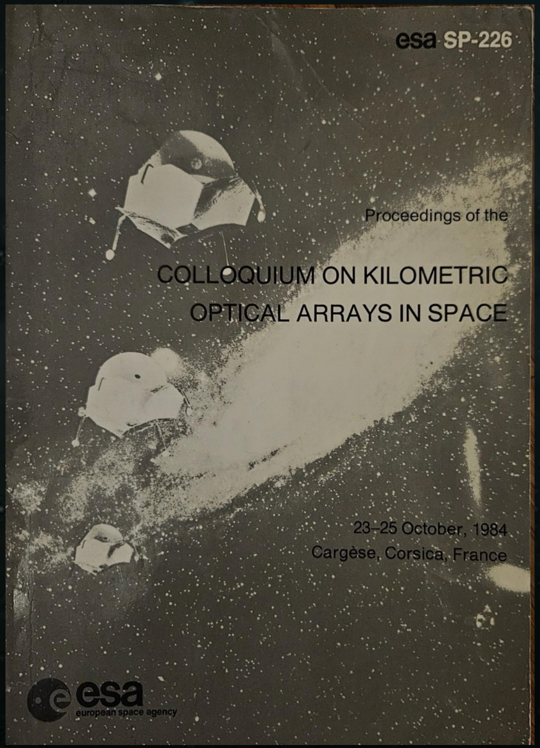


Figure 5

A Space Interferometer Concept

French physicist Pierre Connes, father of the Fourier Transform Spectrometer, saw Froehly's paper and, at the invitation of Labeyrie, presented "A Fiber Linked Version of Project Trio" (Connes, Froehly, Facq) at the 1984 ESO Conference in Cargese. Addressed issues of coupling, guiding, path equalization, polarization.

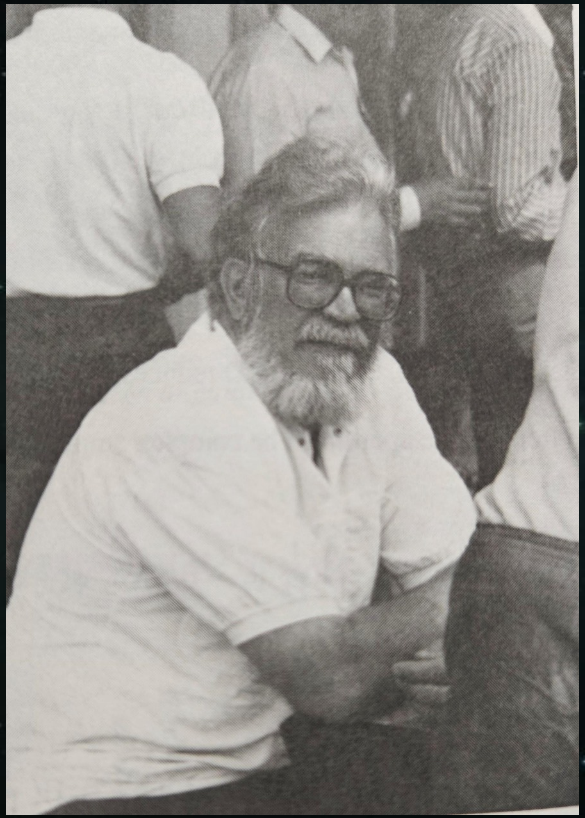



Pierre Connes

At about this time, Francois, Claude and family emigrated to Tucson, Arizona, where Francois and Claude worked in the Advanced Development Program at NOAO on the University of Arizona campus under Jacques Beckers. Francois and Jacques shared a background in solar astronomy.

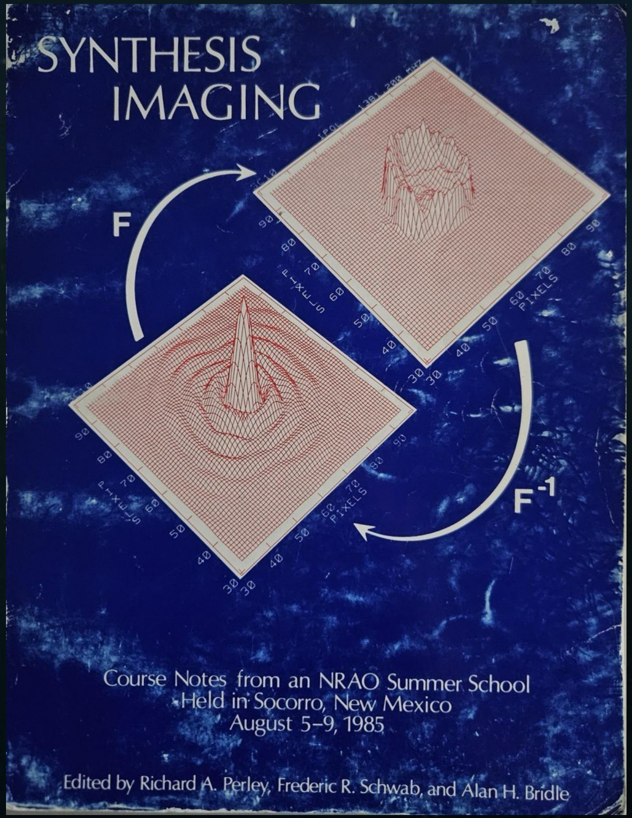

Jacques Beckers

How I met Francois in 1985



Keith Hege in Cargese, 1988

Keith Hege in Los Angeles, 2025 (age 92)



NRAO Summer School, August 1985

EXPERIMENTS AND ANALYSIS AT NOAO

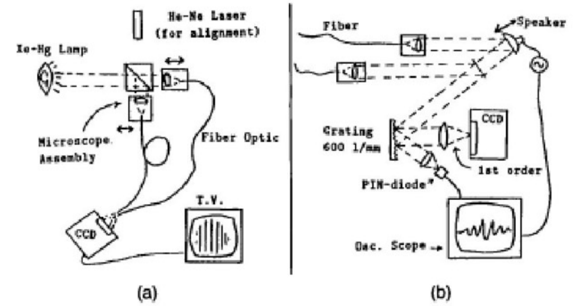


Fig. 1. Experimental setup: (a) input and simple pinhole output; (b) path-scanning output used to produce Fig. 2.

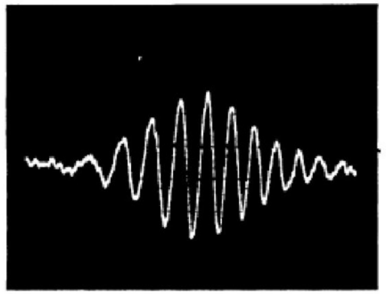


Fig. 2. Typical white light fringe photographed from oscilloscope. The central wavelength is $\simeq 0.8\ \mu m$. The horizontal axis is the optical path difference. The vertical axis is the intensity of light on the PIN diode.

Shaklan and Roddier, SM Fibers in a Long Baseline Interferometer, Appl. Opt 1987

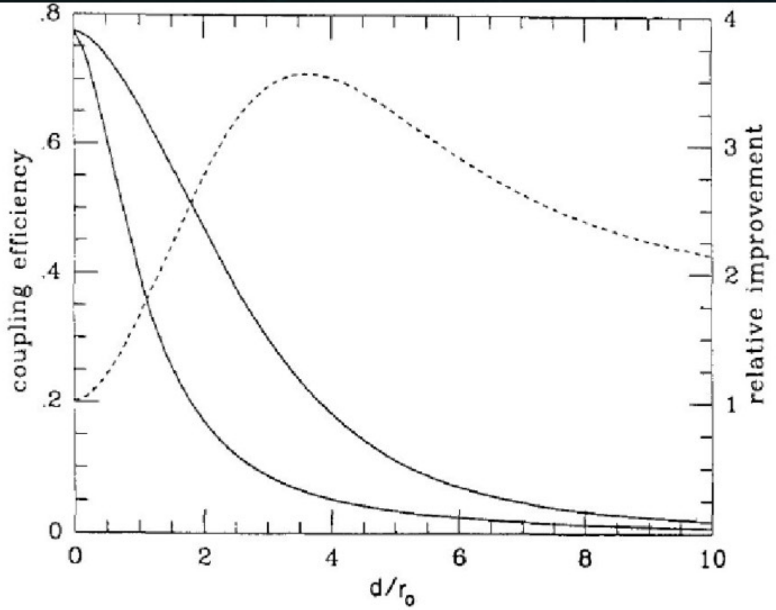


Fig. 2. Coupling efficiency vs seeing at $V = 2.2$. The upper curve is the image stabilization case; the lower curve is for no stabilization. The dashed curve goes with the scale on the right and is the ratio of the two solid curves.

Shaklan and Roddier, Coupling Starlight into SM fibers, Appl. Opt 1988

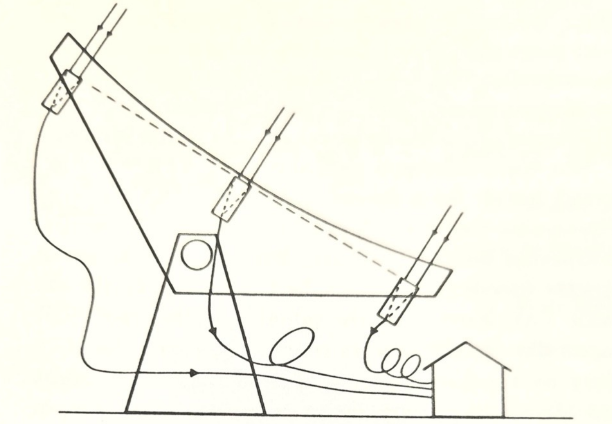


Figure 2: Radio–telescope mounted array of small optical telescopes.

Our radio-telescope proposal can be presented as a test bench for a future space version: the Large Deployable Reflector [7] (a proposed 20 m telescope, diffraction limited at $30\mu m$, but unusable at much shorter wavelengths) might be treated in exactly the same way, hence acquire valuable visible and NIR capability. In the shorter range, piggyback-riding to glory on the bare bones of a dead radio dish might provide a nice revenge for poor optical telescopes, of late sadly far behind in the race for high resolution.

Connes, Shaklan and Roddier, A Fiber Linked Ground-Based Array, ESO-NOAO Workshop, Oracle, AZ, January 1987

First Multi-telescope Imaging, First 5-telescope Beam Combiner

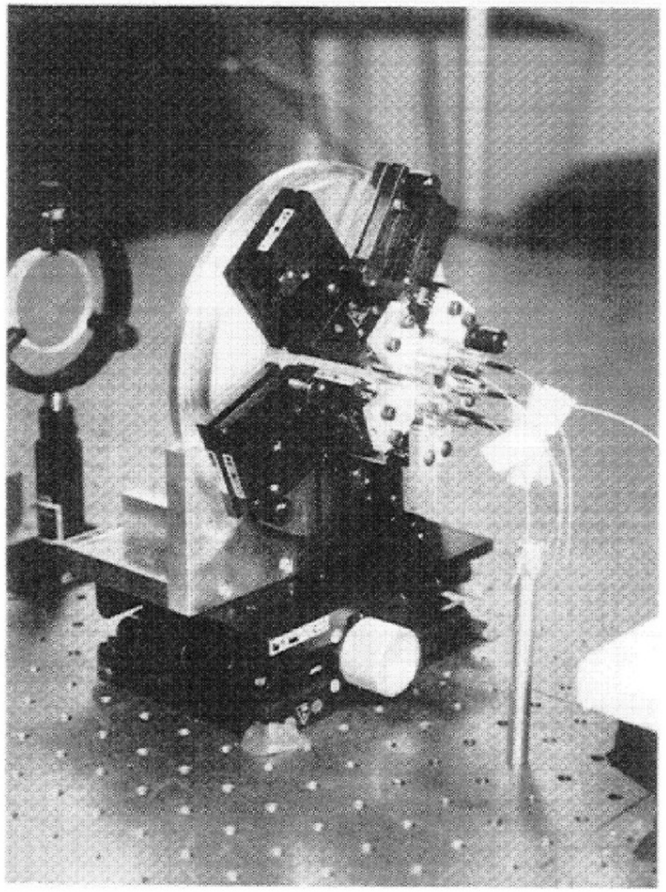


Fig. 3. Rear view of telescopes. Each telescope has its own tip-tilt stage, translation stage (for phasing), and one SM fiber.

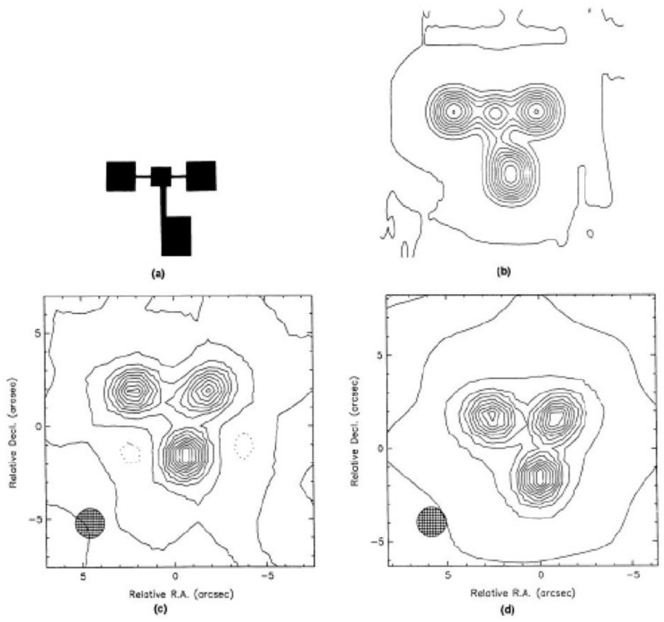


Fig. 4. (a) Negative print of object ("satellite") transparency. (b) Object smoothed by Gaussian with FWHM = 1.6 arcsec. Contour levels are 10% steps from 0. (c) Reconstruction from five telescopes, after self-calibration. The CLEANed map has been smoothed by the same Gaussian as (b) (FWHM shown in hatched region). Contour levels are −10%, 0%, 10%,...,90% of peak. (d) Computer simulation of laboratory experiment. Noiseless amplitudes and closure phases are processed in the same self-calibration loop as the laboratory data. This is the "ideal" experimental result given the object and Fourier plane coverage.

Shaklan, Fiber Optic Beam Combiner for Multi-Telescope Interferometry, Opt. Eng. 1990

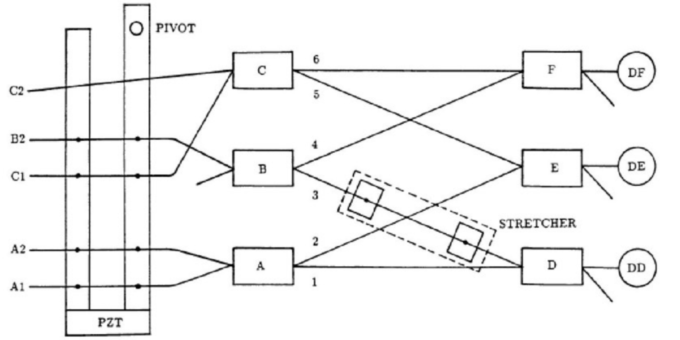


Fig. 1. Schematic of the beam combiner. A1–C2: input SM fibers from telescopes. PZT: Piezoelectric transducer. Pivot: flexure hinge. The PZT and lever arm introduce optical path fluctuations by stretching fibers; this provides temporal modulation of fringes. A–F: 50/50 directional couplers. 1–6: "internal" SM fibers. Stretcher: translation stage and base. DD–DF: photomultiplier tubes. Dots: epoxy.

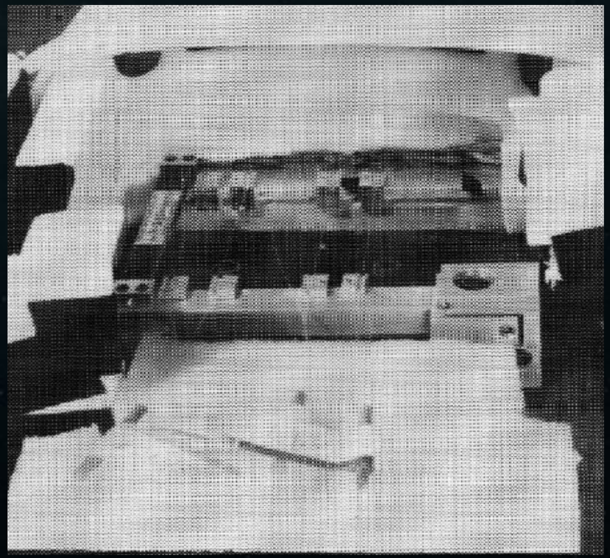
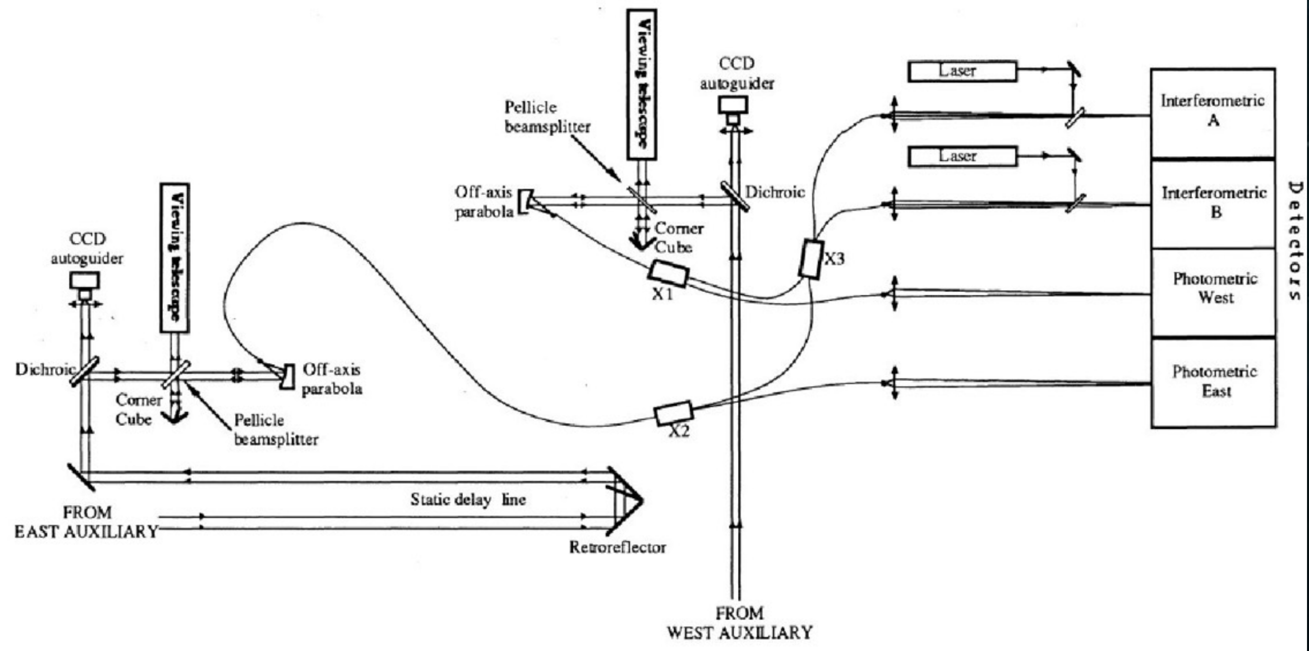


Photo from Shaklan Dissertation, UA 1989

FLUOR: Fiber Linked Unit for Optical Recombination Coude du Foresto et al 1990+



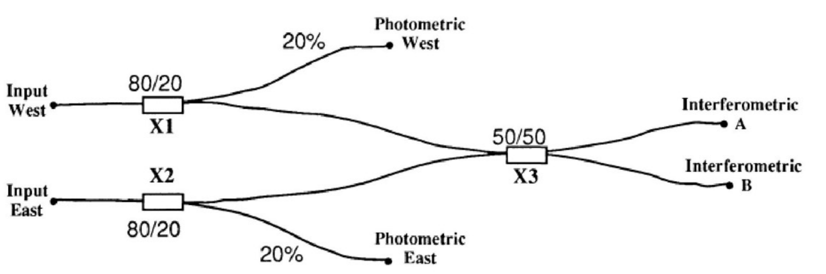


Figure 2: principle of the triple coupler in FLUOR.

This important breakthrough using fluoride-based fibers followed closely on the heels of our laboratory tests. It brought into play the K band (2-2.5 um) and L band (3.4 – 4.1 um) where turbulence is greatly reduced compared to the visible.

On-sky tests using a pair of auxiliary siderostats at the McMath telescope at Kitt Peak.

In use at the IOTA interferometer on Mt. Hopkins.

Later, implemented at CHARA.

A Brief Detour: Cargese Meeting on Diffraction-Limited Imaging with Very Large Telescopes, 1988.

This illustrates how we designed interferometers before we all had desktop computers.

Francois and Yves Rabbia in Cargese, 1988

Chris Haniff and Hans Zinnecker in Cargese, 1988

To complete the story, we bring Claude Froehly back into the final scene.

METIERS

Stuart SHAKLAN

Un Américain à Limoges pour réaliser le plus grand télescope du monde

UN jeune Américain, Stuart Shaklan, est à Limoges pour quinze mois. Il s'intègre aux équipes de recherches de l'I.R.C.O.M. pour tenter de trouver un système de liaison avec des fibres optiques entre plusieurs télescopes.

Stuart Shaklan arrive de l'observatoire de Tucon dans l'Arizona, où il a passé sa thèse le 14 juillet. Ce ne pouvait être qu'avec succès pour cet amoureux de la France.

« Si je suis ici, c'est parce que j'ai envie de connaître la culture et... la nourriture françaises, mais aussi parce que l'équipe optique de la Faculté des Sciences est très intéressante. »

Stuart Shaklan, avec les chercheurs de l'I.R.C.O.M., va tenter de trouver le moyen de réunir plusieurs télescopes par des fibres optiques. Il est, en effet, difficile de réaliser des télescopes de plus de dix mètres de diamètre. Mais certains scientifiques pensent qu'en en associant plusieurs petits répartis sur un vaste terrain, par exemple d'un hectare, on arrive à constituer un immense télescope de cette surface.

« Ici l'équipe est très forte en fibres optiques, estime Stuart Shaklan, *et j'ai déjà des pistes de recherches intéressantes. »*

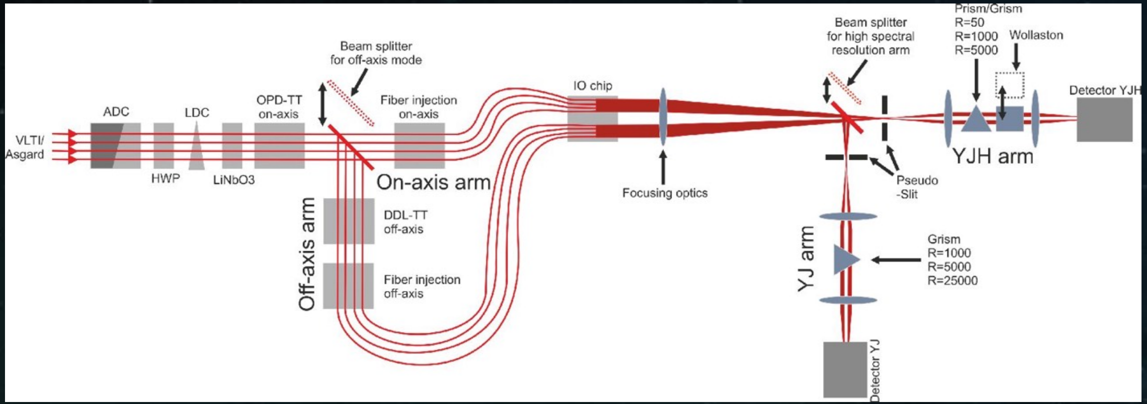
Cette venue à Limoges de cet étudiant de l'université de l'Arizona constitue une reconnaissance des capacités scientifiques du pôle optique électronique et micro-ondes de la Faculté des Sciences de Limoges.

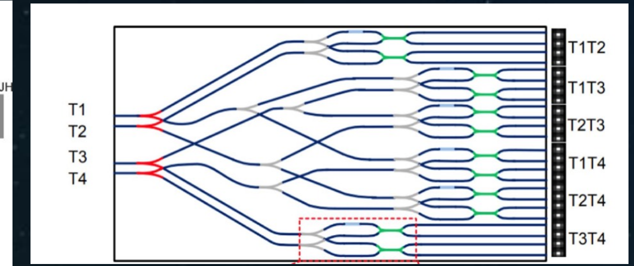
Stuart Shaklan est l'un des dix boursiers de la « National Sciences Foundation ». Une preuve de plus de la cote des équipes de l'I.R.C.O.M. aux U.S.A.

10 – « Le Populaire du Centre » – Mardi 24 octobre 1989

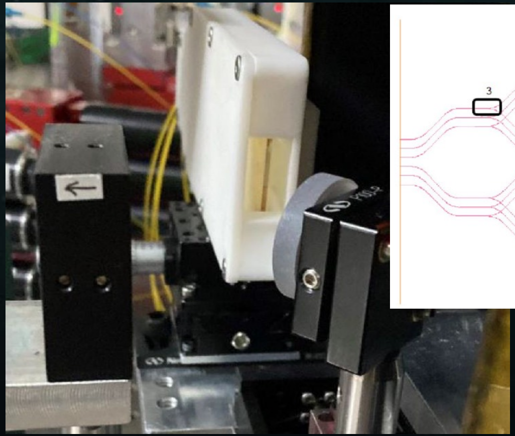
Modern Day Integrated Optics Beam Combiners

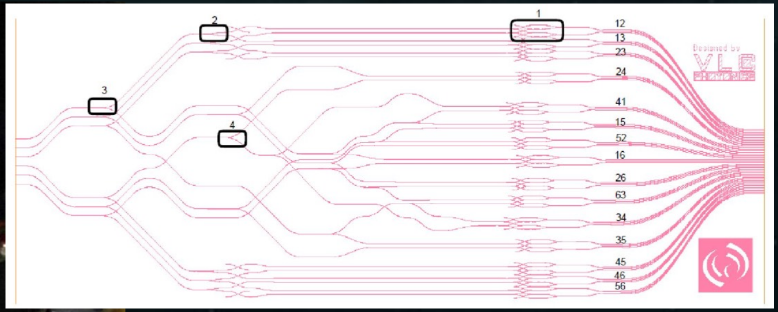
GRAVITY chip at VLTI and CHARA





Mortimer et al, BIFROST Combiner at VLTI (duplicate for off-axis source)





Panettier, Mourard, Monnier e al, SPICA-FT integrate optic a CHARA

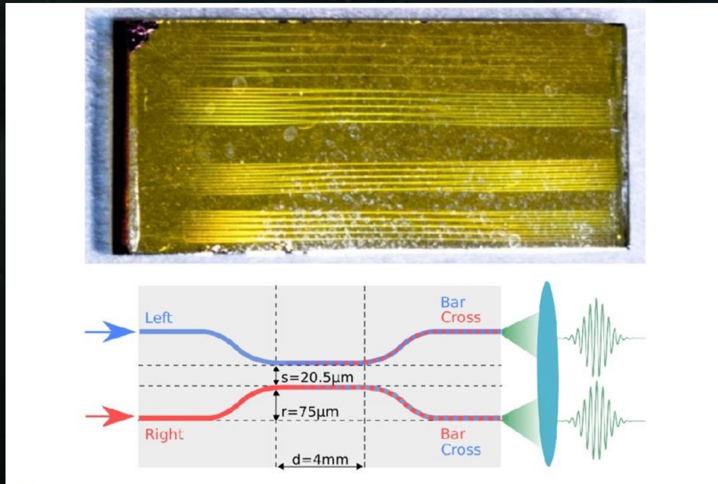
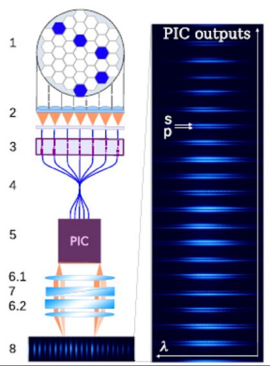


Fig. 1. *Top*: integrated optics chip including 20 two-beam combiners written with different parameters. *Bottom*: dimensions of the chosen two-beam combiner used in this paper and labeling of the waveguides. The terms bar and cross are used to distinguish the output of the initially excited waveguide from the evanescently coupled arm output.

Tepper et al, L & M Band beam combiner 2017

Lallement et al, Photonic Beam Combiner for Subaru, JATIS 2023



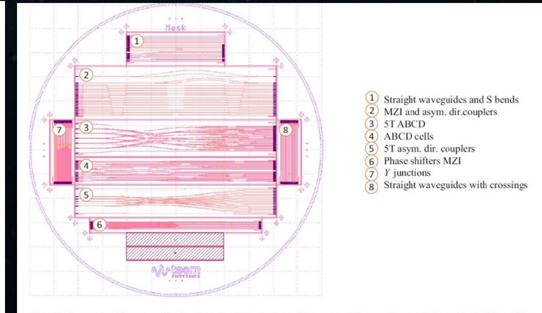


Fig. 15 Latest wafer graphic design system view on Klayout software. It comprises test PICs with simple functions to characterize fundamental properties of the waveguides, as well as isolated combiner functions (asymmetric directional couplers and ABCD cells) and also two complete 5T-combiners.

Conclusion

Francois Roddier played a major role in analyzing long baseline interferometer performance, defining configurations and observation strategies, and in the architectural approach to beam recombination. He was an important link connecting classical interferometers to today's modern photonics. From his theoretical treatment, to the first conversation between Labeyrie, Froehly, and himself, to our first experiments in fiber-linked interferometers, his contributions have greatly advanced the field and will continue to do so with future generations.