

Interferometry and Stellar Interferometers

But How Do You Build One?



Theo ten Brummelaar

CHARA – Georgia State University

Interferometry and Stellar Interferometers

Warning: This talk will contain
opinions.

These opinions are mine, and do not reflect the views of the MSC.

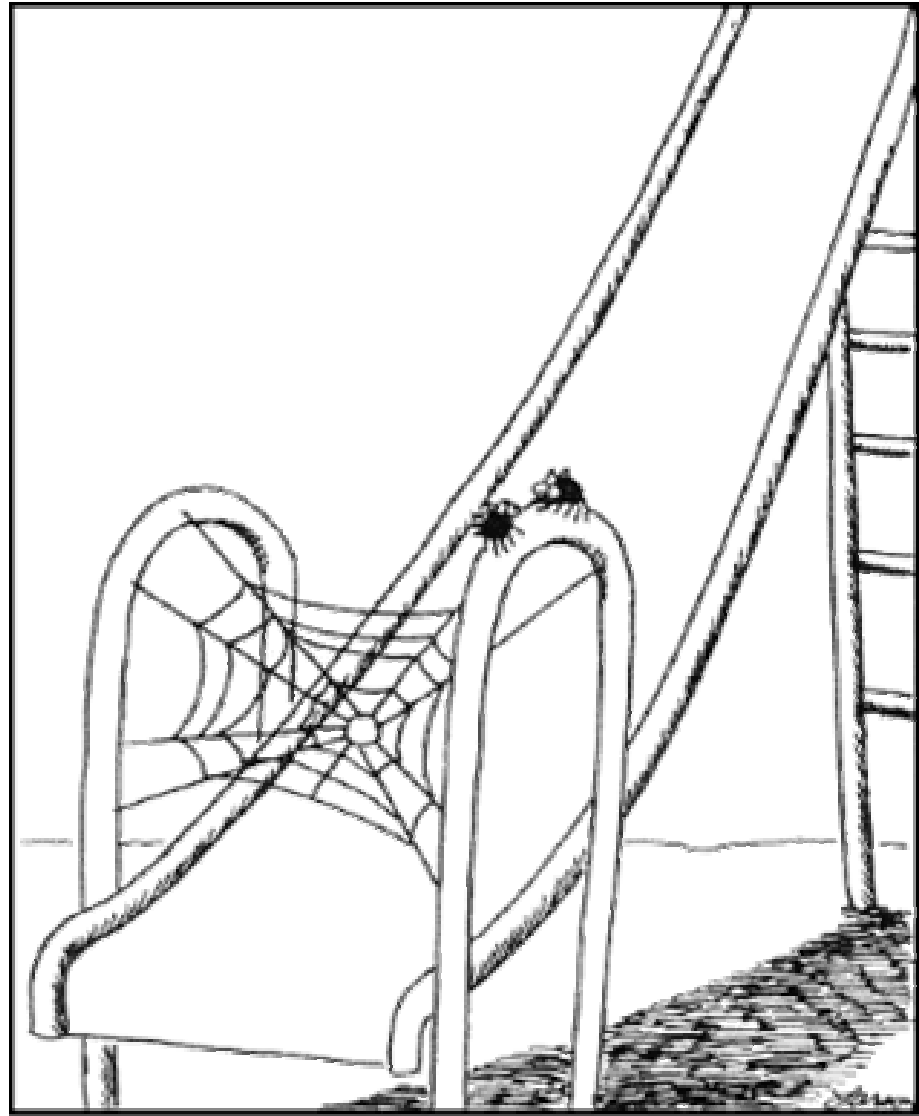
So if you have a problem with anything I say don't annoy Gerard about it, come talk to me.

Of course, coming to a school like this you must expect to hear opinions a lot of the time. After all, you are here to pick up the intellectual droppings of your seniors, aren't you? Or is it the free trip to Los Angeles that brought you here? In any case you shouldn't be upset if I say something bad about your favorite interferometer. What do you know about the subject anyway? The fact that you're here listening to this stuff means that you either wish to learn or have come here to meet other students, even find a potential mate like Mike Fischer did. So sit back, relax and listen up, or not, just don't get upset. Hell, this isn't important enough to raise your blood pressure really is it?

Interferometry and Stellar Interferometers

Optical Interferometry is not easy. Building them is hard, collecting the data is difficult, and calibrating that data is all but impossible.

Interpreting the final result is even harder, and can lead to embarrassment, even press releases you may come to regret.



"If we pull this off, we'll eat like kings."

Things to Think About

- Operating wavelength, bandwidth, site location
- Match apertures to r_0 ?
- Tip/tilt and/or adaptive optics
- Optical path length compensation & phase stability
- Dispersion: vacuum or air?
- Metrology

More Things to Think About

- Optics: quality & quantity
- Coatings
- Polarization—dynamic & geometrical phase shifts
- Diffraction
- Control & data acquisition systems

Even More Things to Think About

- Beam Combination Scheme: Fringe Modulation Temporal or Spatial ?
- Fringe tracking: Separate from Science Engine ?
- Spatial Filtering ?
- Use of Fibers: Before or after Beam Combination ?

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Name	Institution	Site	Number of Elements	Element Aperture (cm)	Max. Baseline (m)	Operating Wavelength (microns)	Operating Status
GI2T	CERGA	Calern	2	150	35	0.4 - 0.8 & >1.2	since 1985
COAST	Cambridge U	Cambridge	4	40	100	0.4 - 0.95 & 2.2	since 1991
SUSI	Sydney U	Narrabri	13	14	640	0.4 - 0.66	since 1991
IOTA	CfA	Mt. Hopkins	3	45	38	0.5 - 2.2	since 1993
ISI	Berkeley U	Mt. Wilson	3	165	30(+)	10	since 1990
NPOI	USNO/NRL	Anderson Mesa	6	60	435	0.45 - 0.85	since 1995
PTI	JPL/Caltech	Mt. Palomar	2	40	110	1.5 - 2.4	since 1995
CHARA	Georgia St. U	Mt. Wilson	6	100	350	0.45 - 2.4	since 1999
Keck	CARA	Mauna Kea	2(4)	1,000(180)	165	2.2 - 10	initial 2001
VLTI	ESO	Cerro Paranal	4(3)	840(250)	200	0.45-12	initial 2001
MIRA	NAOJ	Tokyo	2	13	30	??	initial 2002

Site Selection Concerns

- Morphology
- The atmosphere above
- The ground below
- Vibration
- Facilities
- Location

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KECK: Sierra Club member opposes plan

From Page 1

A draft of an environmental assessment report was completed in December 2000 but the final report is not expected until March or April.

Ho wrote to DLNR Chairman Gilbert Coloma-Agaran and the board that the permit application is premature, and that the IfA is recommending the project without an environmental impact statement, which entails a more critical look at the potential impact of the project.

"Every agency and community organization that reviewed the NASA Environmental Assessment — including the university's Office of Mauna Kea Management — made the opposite recommendation," Ho wrote.

Walter Heen, former interim director of the OMKM, said it is "inaccurate to say there is no, or at most minimal, impact from the construction activity necessary to install the ... outrigger telescopes."

Heen said excavation for the telescopes could disturb ancient burial sites, and that native Hawaiian cultural concerns are "deserving of greater in-depth analysis." A lack of understanding for the impact of the con-

struction project in spiritual terms renders the Keck plan "utterly inadequate," he said.

The project would use less than half an acre of the five-acre site subleased for the W.M. Keck Observatory for its outrigger telescopes project, which includes the addition of six 1.8-meter telescopes on the site. Only four would be built in the initial phase.

The outriggers would be used in conjunction with the existing twin Keck telescopes in a process called "interferometry," which increases their light-gathering power. NASA said the \$50 million project will provide a boost to its "Origins" program, which studies the beginnings of the universe and searches the heavens for planets that could support life.

The new project would be paid for by the National Aeronautics and Space Administration.

John Lee, a spokesman for the Keck Interferometry Project in NASA's Washington, D.C., office, said Thursday that the final draft of the environmental assessment, which would address the Hawaiian community's concerns, is being pre-

pared, along with an agreement that would satisfy all parties interested in the project.

NASA is still reviewing the reaction to its environmental assessment. "We're taking all the comments very seriously," Lee said. The final EA could be ready in three months.

"If we had our druthers we would have been building two years ago," Lee said, but community concerns for the impact of the project on Mauna Kea and other factors have put the project behind schedule.

The decision whether NASA will seek approval of the project with just the environmental assessment, not a full environmental impact statement, has not been made and will be up to the "senior management" at NASA. "The issue is to address the issues, not the document," he said.

Opponents' recourse if NASA fails to seek the full EIS would be a legal challenge.

Last week Clayton Hee, chairman of the Office of Hawaiian Affairs, which also opposed the project without an EIS, proposed that NASA pay more than \$20 million to use the ceded lands atop Mauna Kea, which are leased by the

Institute for Astronomy for the Mauna Kea Science Reserve where the telescopes are located.

Hee asked for \$10 million as an endowment to fund scholarships for undergraduate and graduate studies of astronomy and Hawaiian culture, and \$10 million for five professorships in the same areas of study at University of Hawaii at Hilo.

OHA has previously said it would sue to stop the project if it did not pursue the full EIS.

The Land Board could deny the conservation district use permit if it determined the EIS was needed but rejected by NASA, and no decision by the Land Board on the Conservation District Use permit will be made until the NASA completes its final environmental assessment, said Robert McLaren, IfA associate director. McLaren said the anticipated "finding of no significant impact" from the project indicated in the December OEQC report was probably based on a state environmental assessment prepared in 1999, but that the IfA does not take that position currently. "NASA is taking the lead on this project," he said.

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The Tour Begins.....

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NPOI

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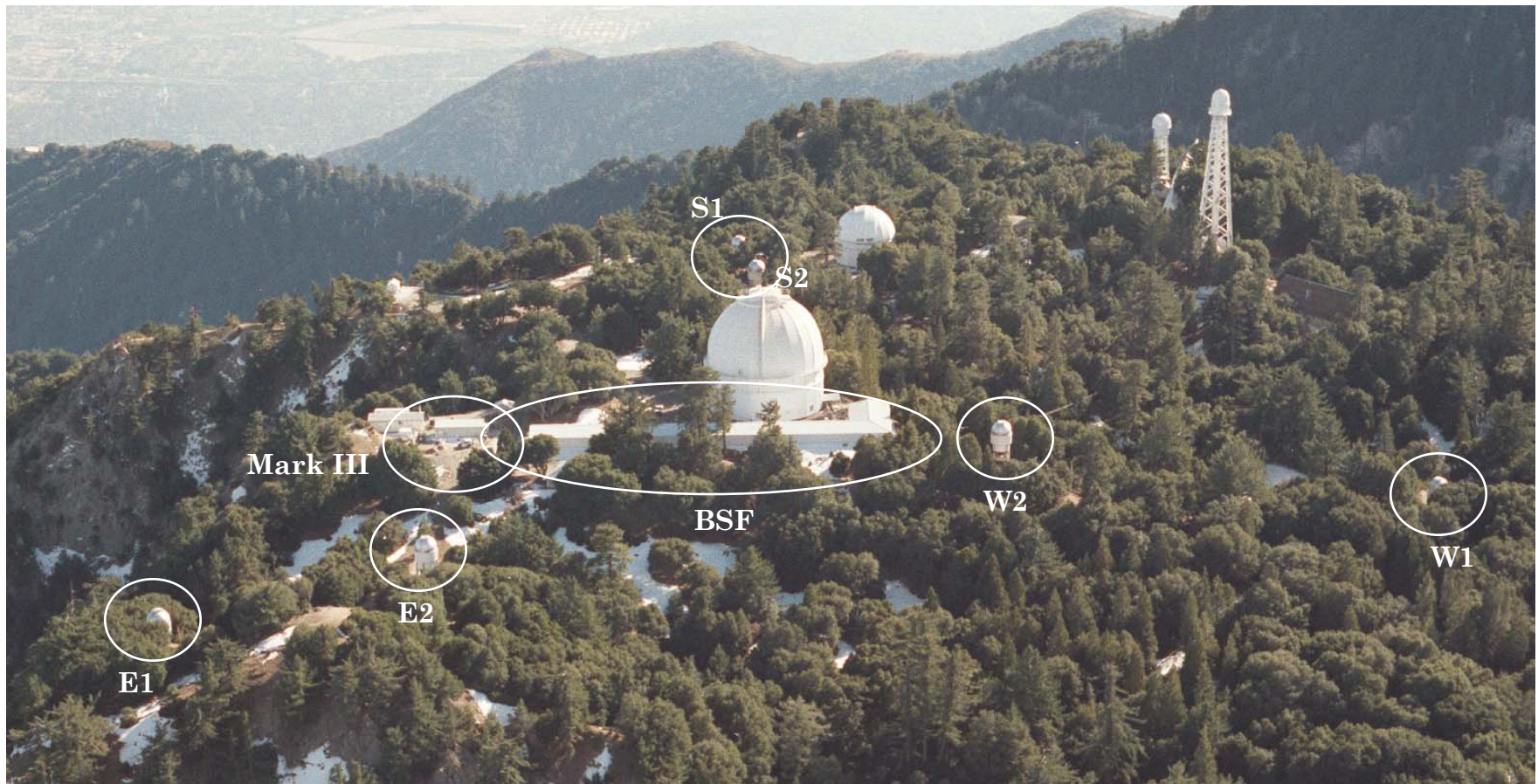
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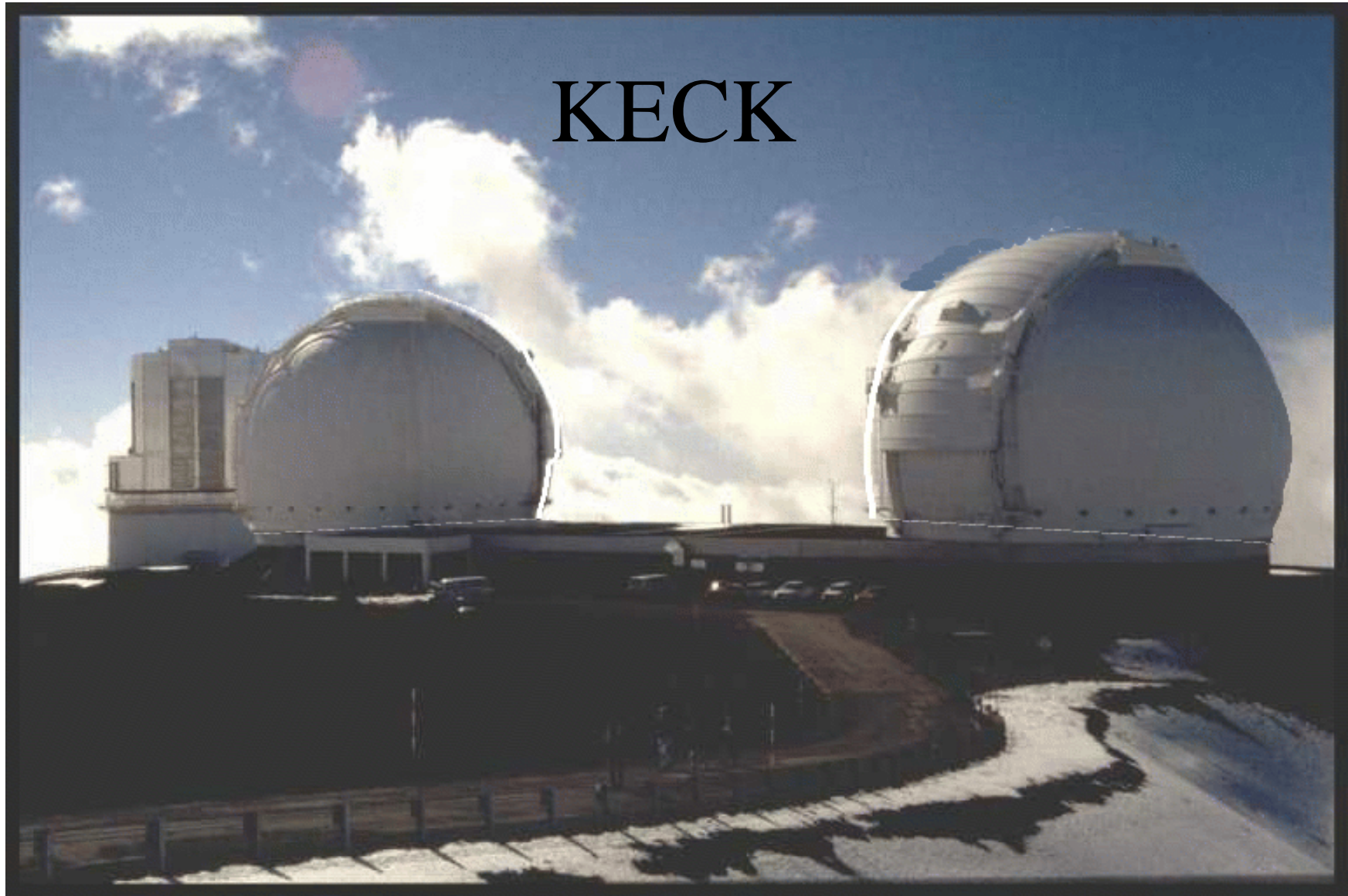


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VLTI



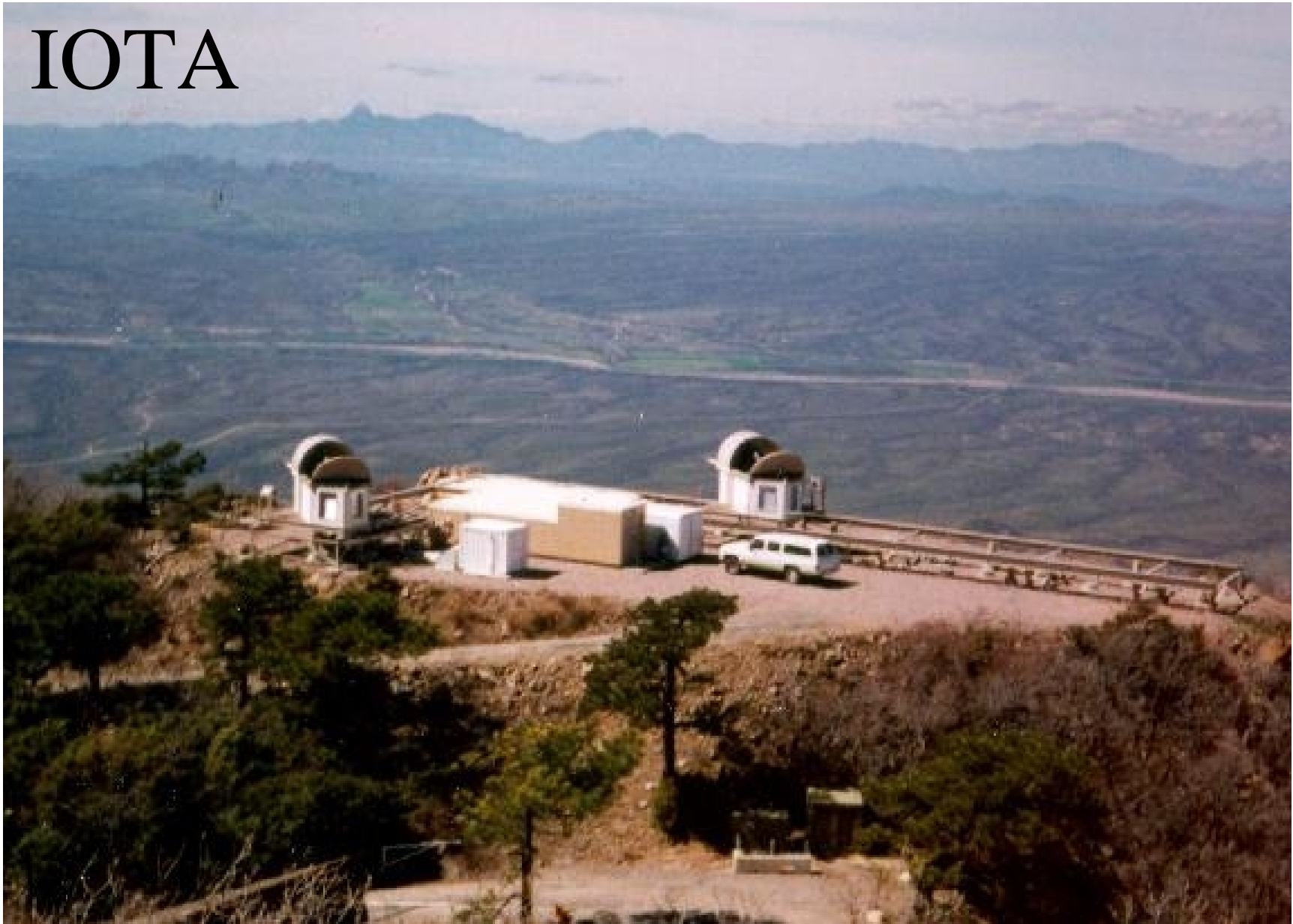
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IOTA



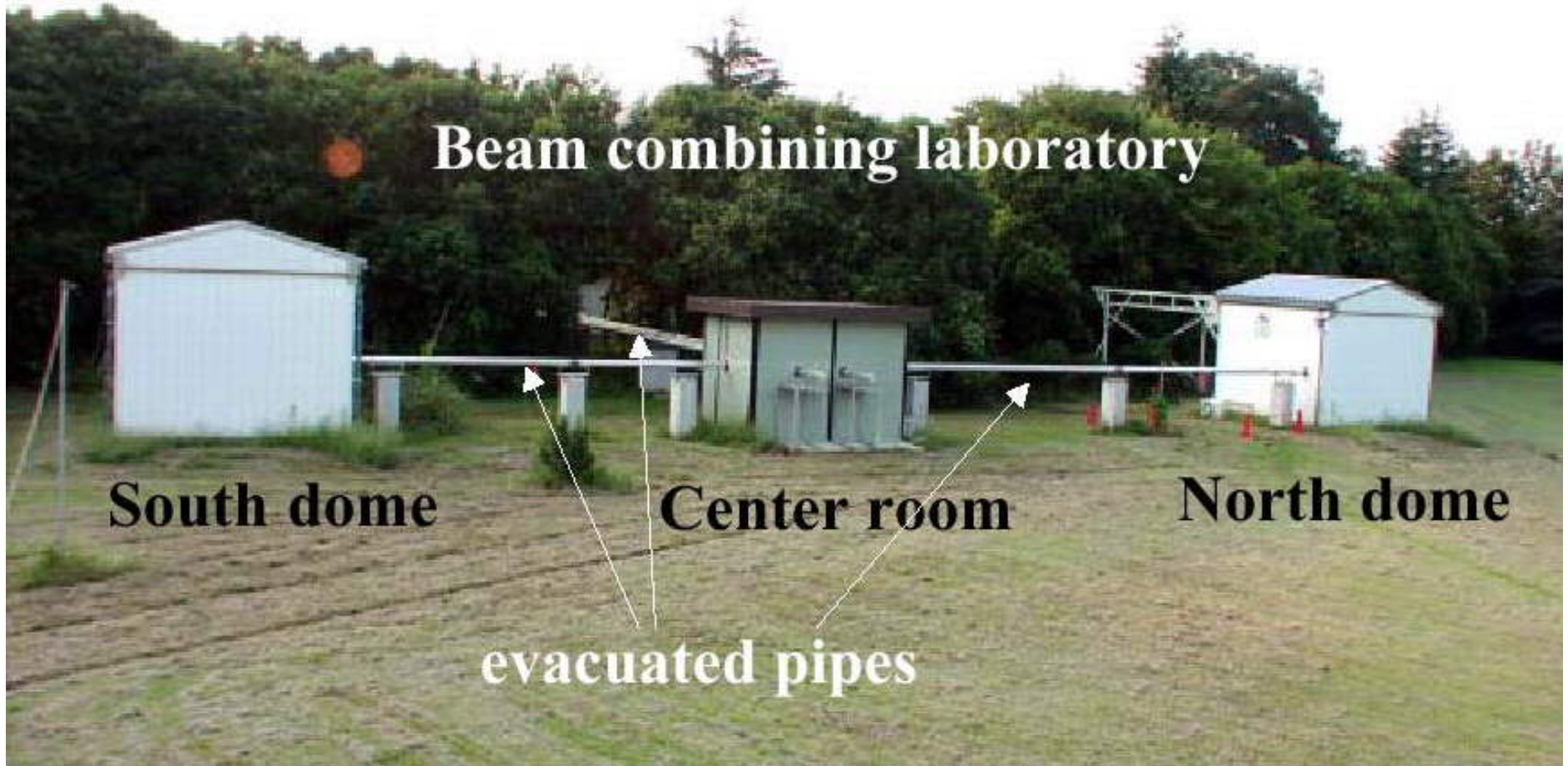
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MIRA



Steel and Concrete

- You need to secure things to ‘bedrock’
- Optical and building foundations must be isolated
- Everything needs to be stable at the micron level
- You need to have a contractor you can trust

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The Light Must Get In Somehow

- Aperture size: seeing and adaptive optics
- Siderostat Vs Telescope
- How many apertures can you afford?
- Movable Vs Stationary

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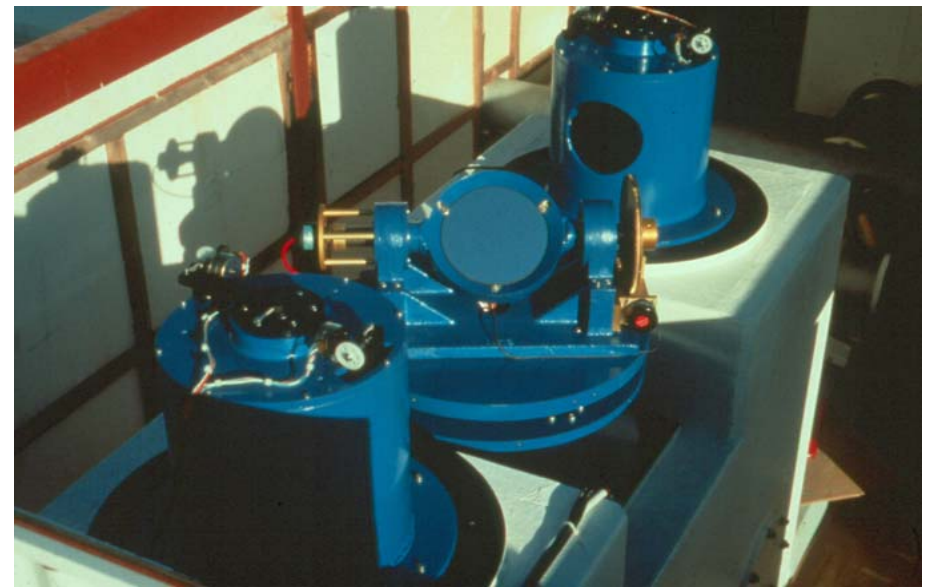
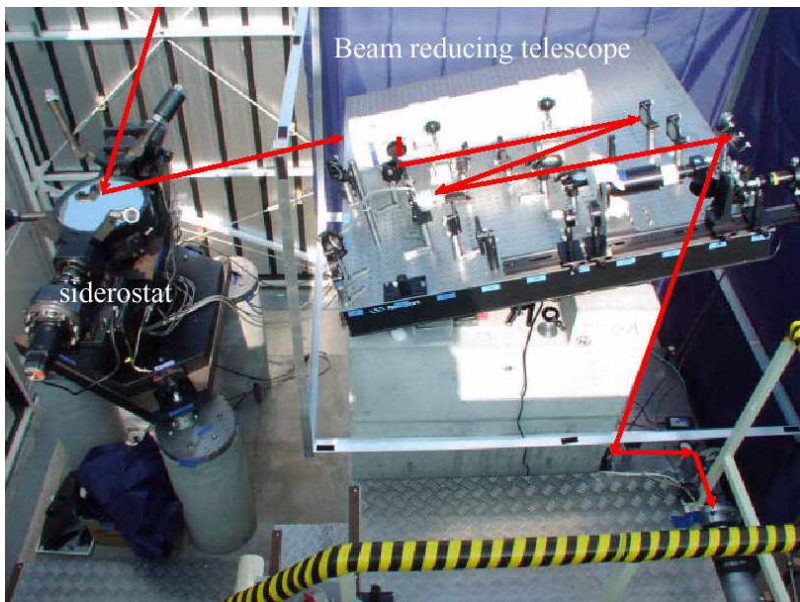


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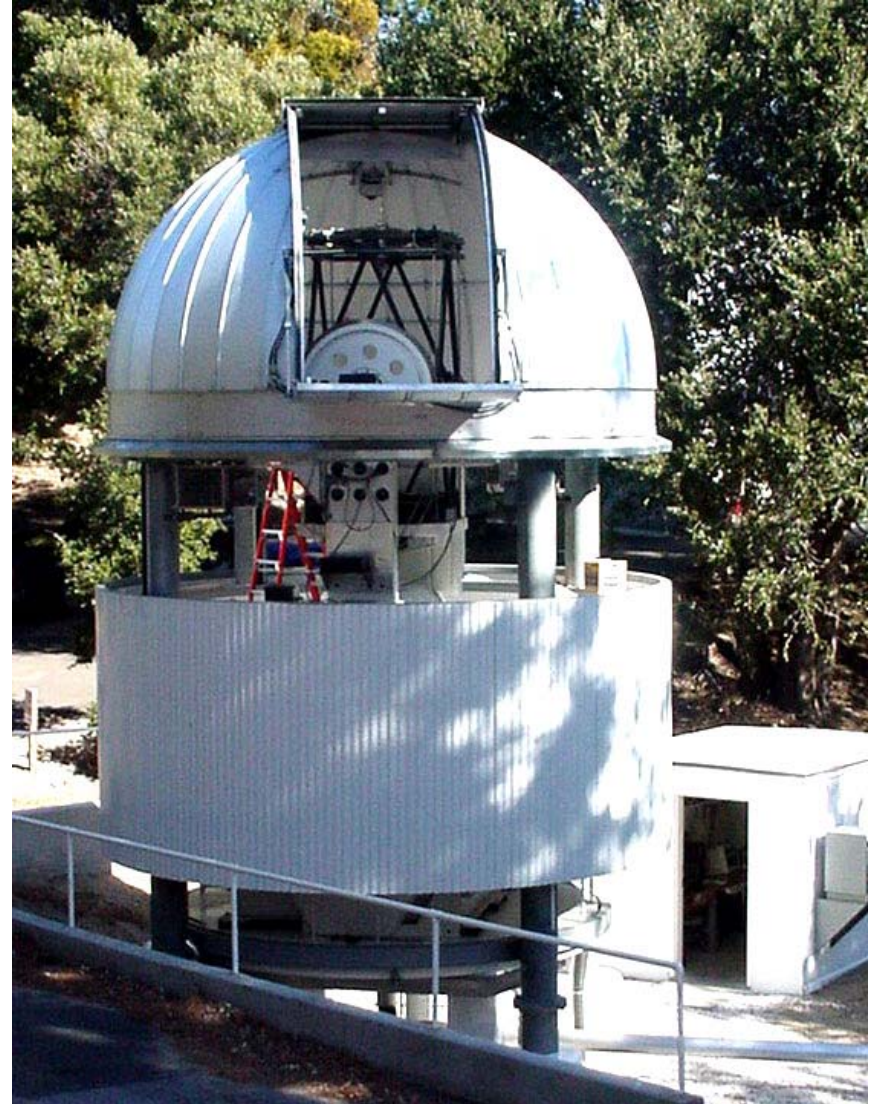


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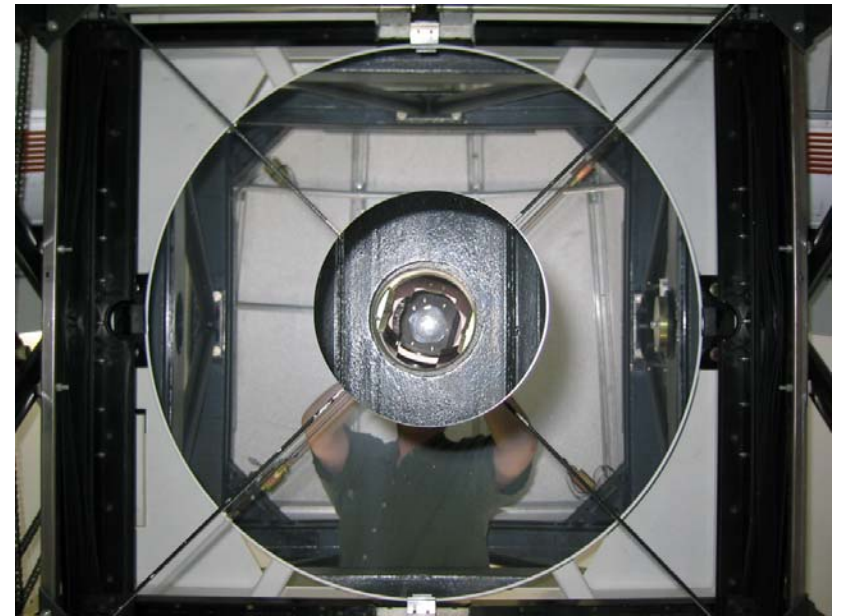
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The Light Has to Reach the Center

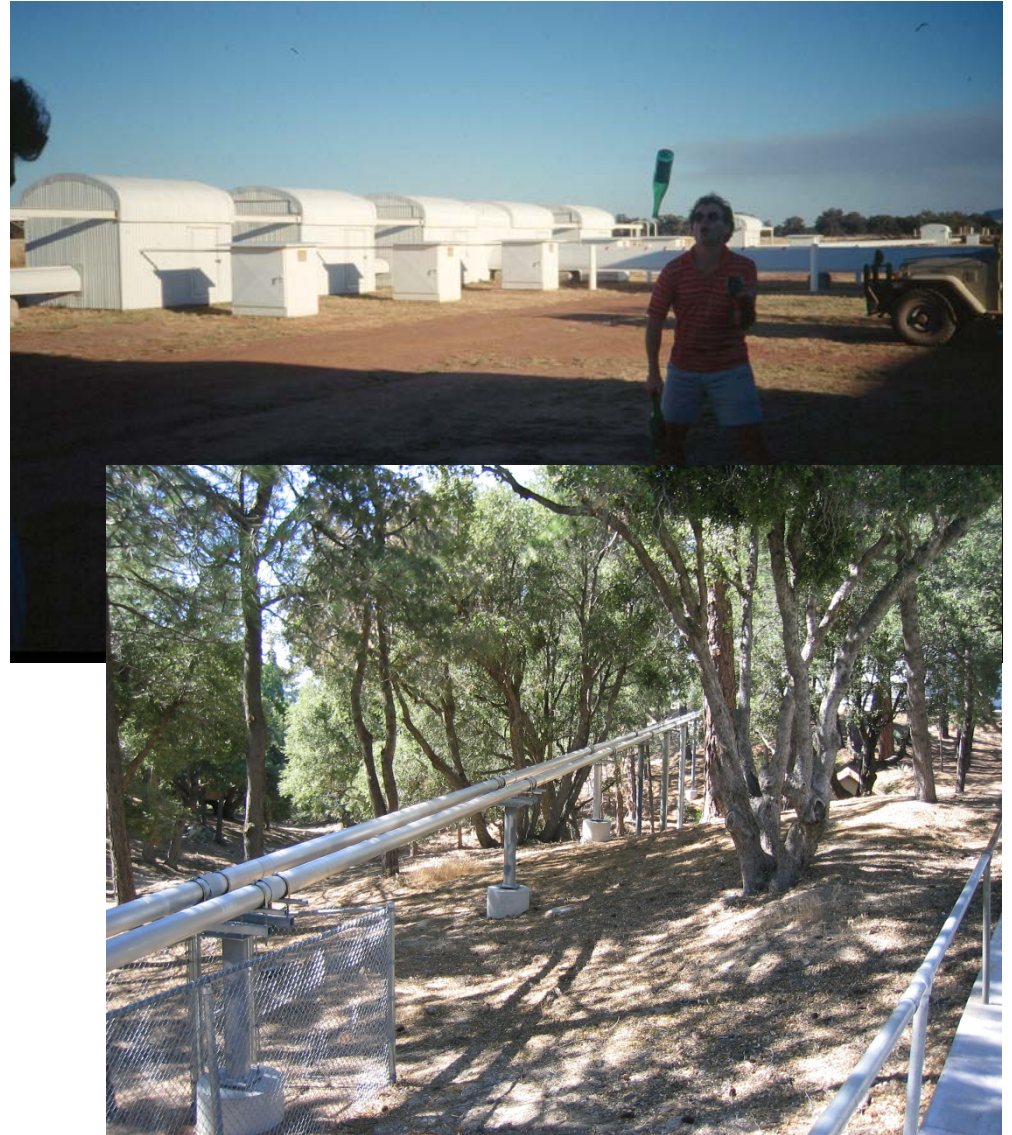


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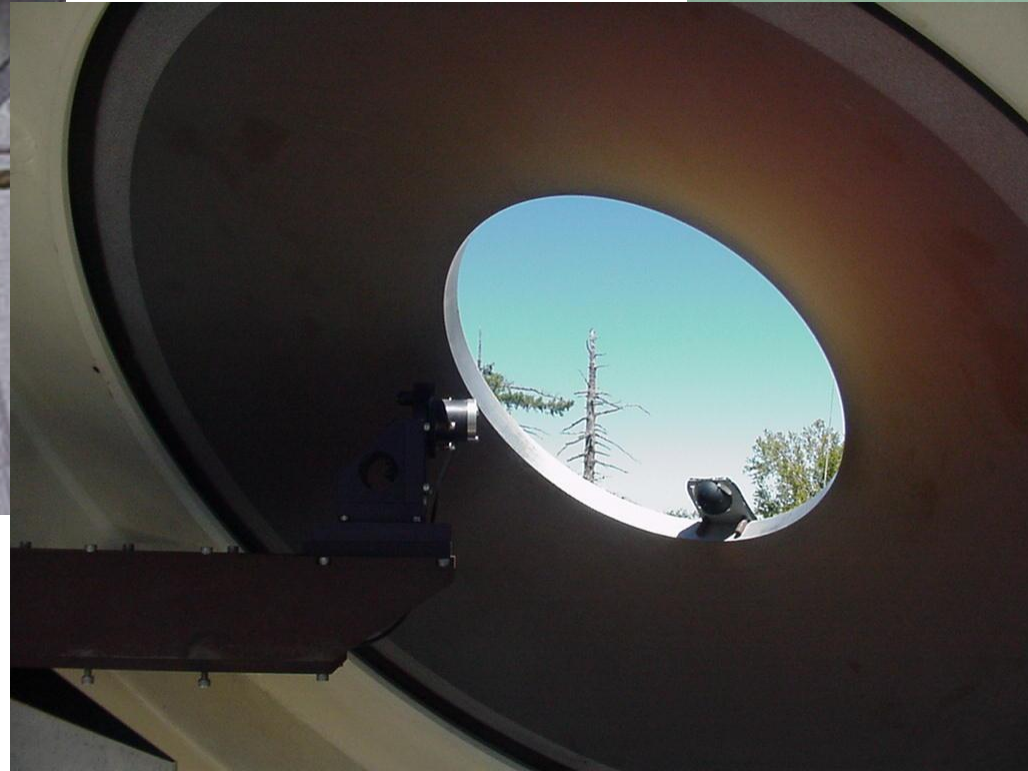
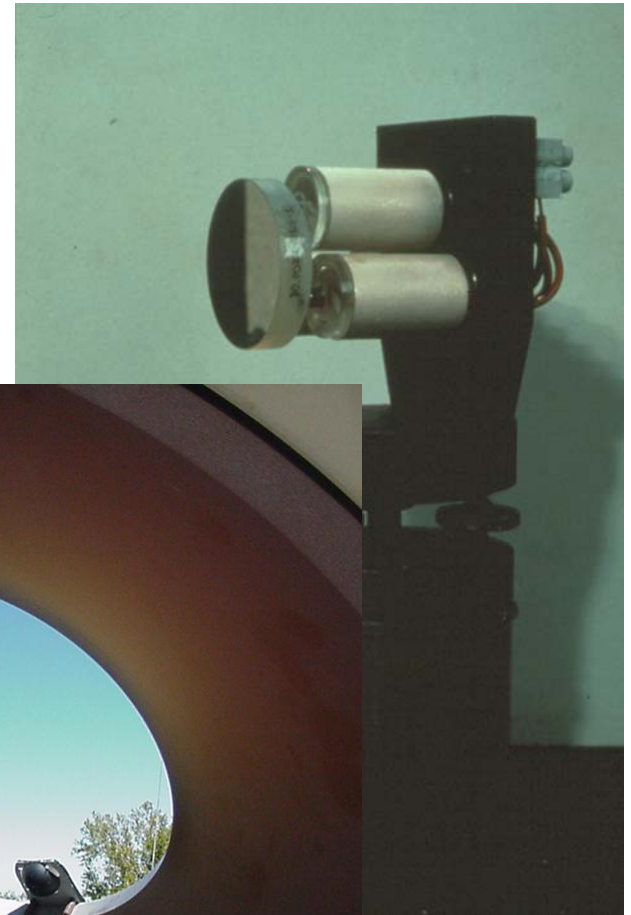
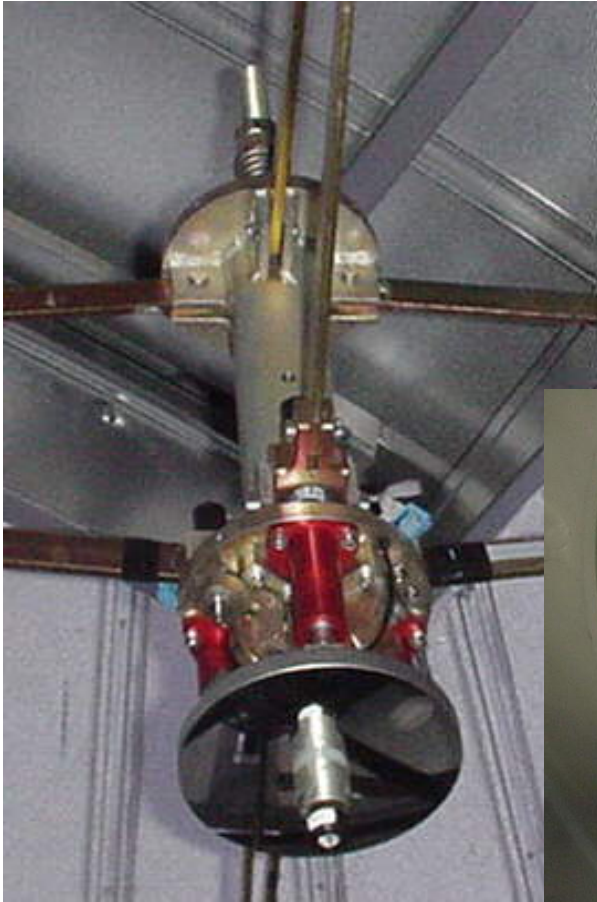
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The Light Needs to be Stable

- You must have tip/tilt
- Your beam size should be well matched to the seeing
- Adaptive optics may help
- The optical train should not introduce any more instabilities (site/mount vibration)

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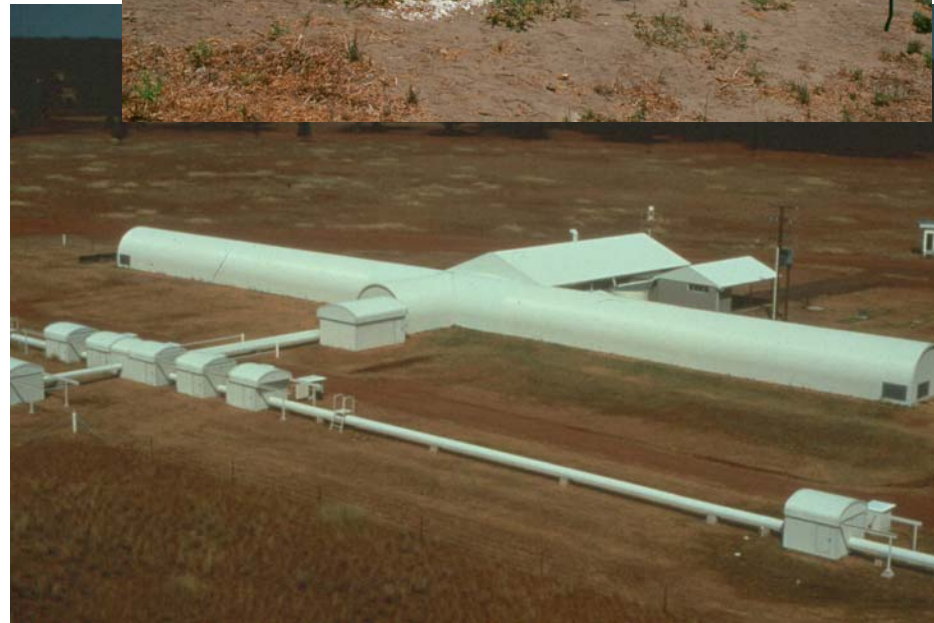
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The Instruments need enclosing....



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.... and Thermal Stability



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Delay Lines sit on Rails....

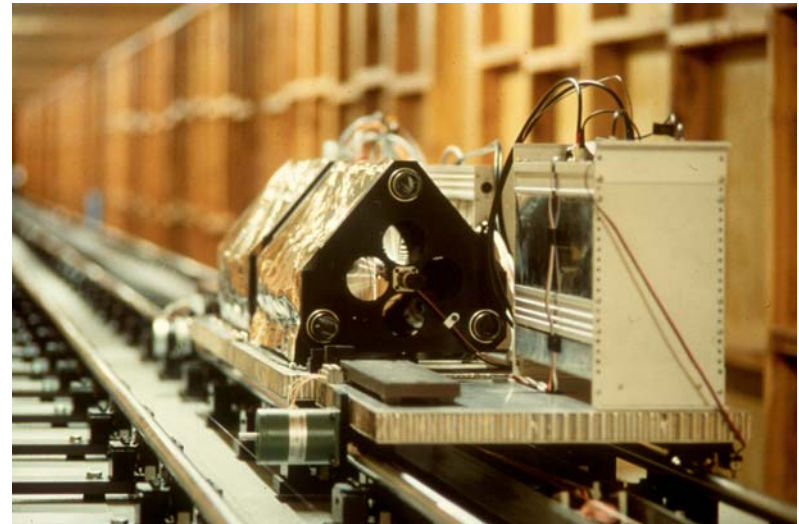
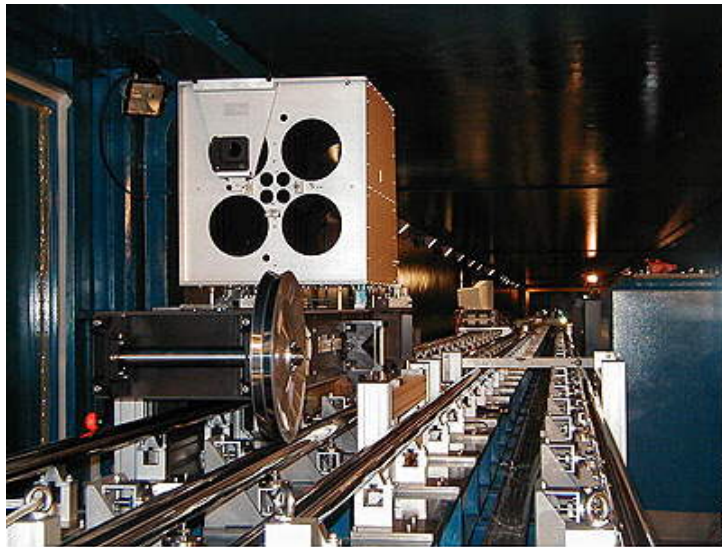
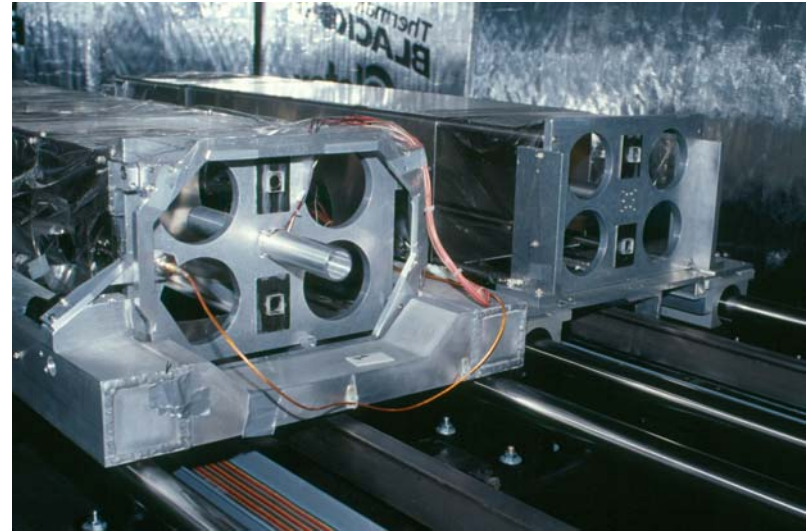
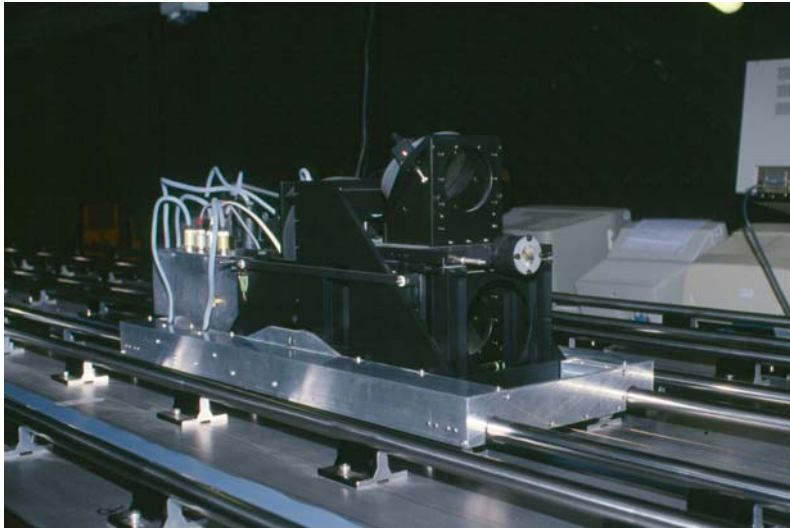


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Interferometry and Stellar Interferometers ... and Delay the Light.



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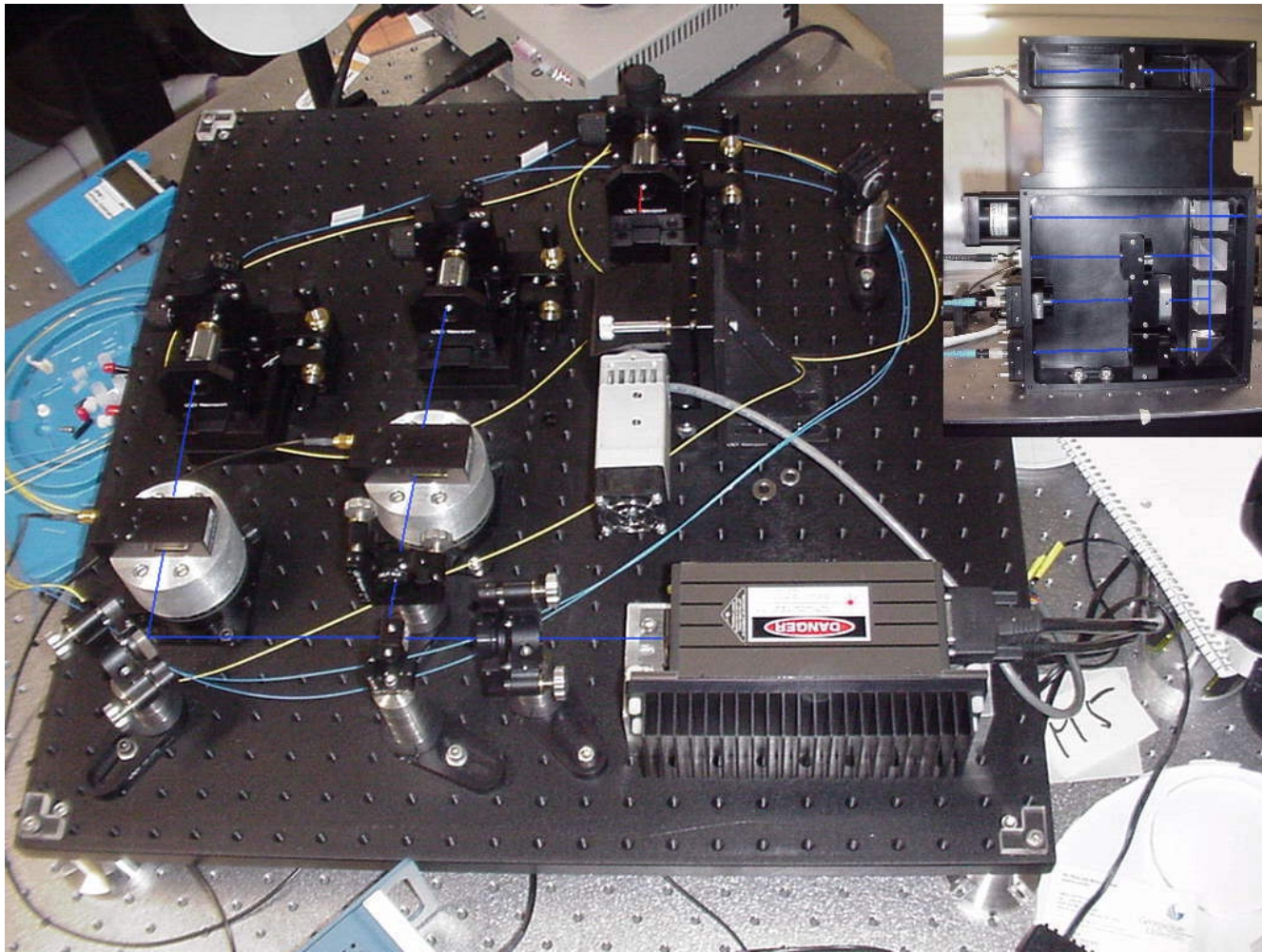
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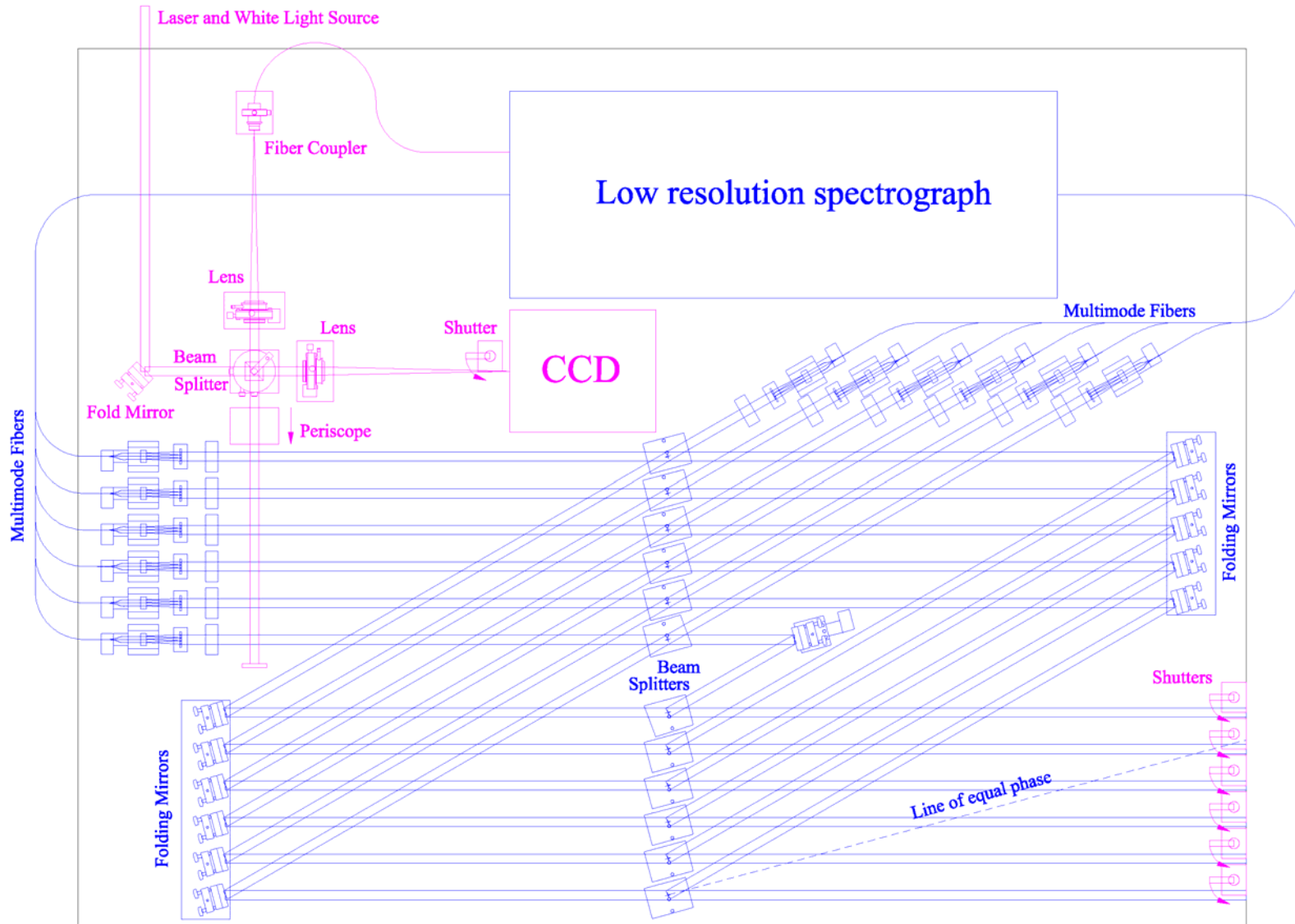
You Need Metrology that Works



What About a Beam Combiner?

- Modulation scheme – temporal or spatial?
- Open air, fiber or a combination?
- How many beams at a time?
- How do you divide the light – gray, color or polarization?
- Are fringe tracking and imaging the same thing?

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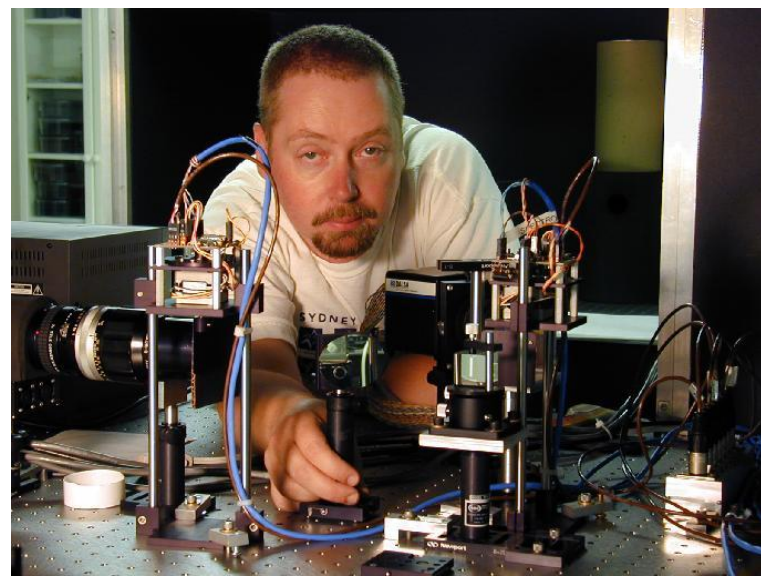
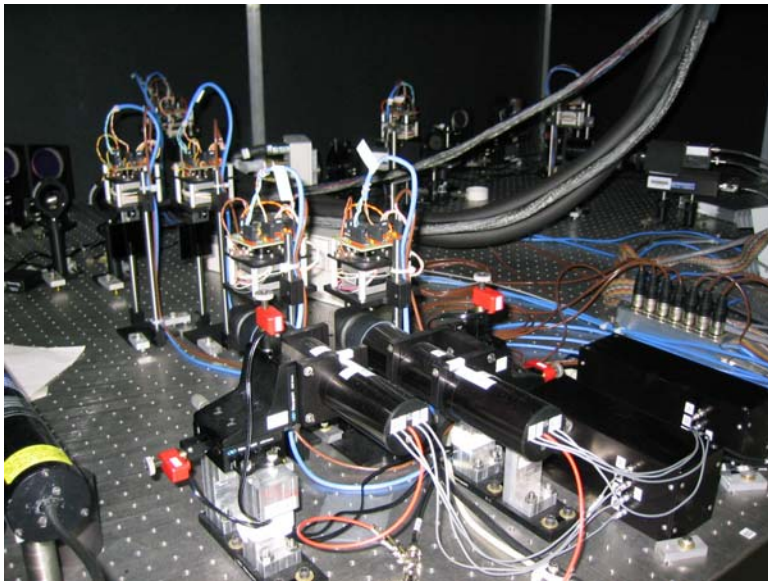
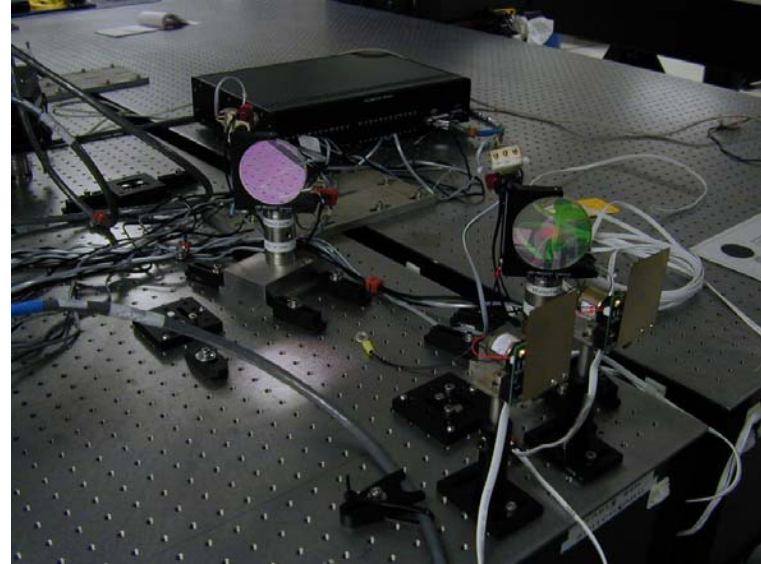
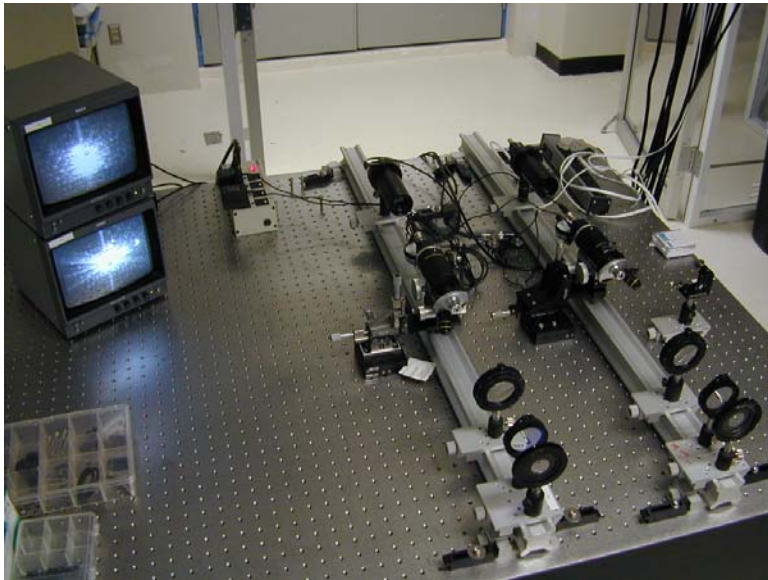


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You will Need a lot of Electronics



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And Don't Forget the Control System



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The screenshot displays the CENTRAL SCRUTINIZER control interface, which is divided into several sections:

- Control Panels:** Located on the left, these include fields for LOCAL TIME (22:37), CHARA#, CALIBRATOR 1 and 2 (with NUM, WHEN, IRC, and RA fields), OBJECT, BAND (K), NRO (1000), and various operational buttons like CLEAR, SYNC GPS CLOCK, and TRACK SOCKET.
- Data Plots:**
 - DIFF UP:** Shows a plot of the upper difference signal.
 - DIFF DOWN:** Shows a plot of the lower difference signal.
 - SUM:** Shows a plot of the summed signal.
 - POWER SPEC:** Shows a power spectrum plot.
- Status and Log:** The bottom-left area contains a text log with the following content:


```

      ople: Data recording stopped for S2.
      irimage: File /irimage/data/2003_07_03_HD_135502_ird_006.dat final Vup = 0.247 Vdn = 0.268
      Beam 3: W1 Beam: 4 S2 Reference: W1
      Next target is OBJECT: CHARA# 176041 HD_139006 ALPHECCA
      wobble: Sample time 5 mS
      astromod command: rsh ctrscrut astromod -b W1 3 -b S2 4 -f W1 -s -o 176041 &
      Telescope slew complete.
      wobble: TOO MUCH LIGHT IN DETECTOR S2, ND IN!
      wobble: TOO MUCH LIGHT IN DETECTOR W1, ND IN!
      wobble: W1 Detector RMS = 0.08" r0 = 5.3cm Seeing 1.20"
      wobble: S2 Detector RMS = 0.09" r0 = 6.0cm Seeing 0.84"
      Star sequence complete.
      Beam 3: W1 Beam: 4 S2 Reference: W1
      Beam 3: W1 Beam: 4 S2 Reference: W1
      Ople positions : W1 = 0.000000004m S2 = 11.624156952m
      Ople errors : W1 = 0.000000001m S2 = -0.000000005m
      wobble: Sample time 5 mS
      irimage: Dither set to 120.000000 Hz for 2.133000 um wavelength
      irimage: Started saving data in /irimage/data/2003_07_03_HD_139006_ird_006.dat
      irimage: Dither running: Range = 87.12um Lambda = 2.133um Frequency = 120.000000 Hz
      irimage: Number of scans for shutter A is 10
      irimage: Number of scans for data is 200
      irimage: Number of scans for shutter B is 66
      wobble: W1 Detector RMS = 0.07" r0 = 4.6cm Seeing 1.33"
      wobble: S2 Detector RMS = 0.07" r0 = 9.0cm Seeing 0.77"
      Record sequence complete.
      ople: Data recording started for S2 file /ople/data/HD_139006_S2_006.dat.
      
```
- IRIMAGE NORM Panel:** A smaller window on the right shows:


```

      /irimage/data/2003_07_03_HD_139006_ird_006.dat
      Scans 129          DATA SCAN 170
      SNR 7.797
      Offset 0          Vup = 0.152          Vdn = 0.178
      
```
- S2 OFFSET Panel:** A central dialog box shows:


```

      S2 OFFSET
      START: -4948.932 POS: -1548.932
      Large: 75.000
      Small: 25.000
      
```
- Terminal:** The bottom-most section shows a terminal window with commands like 'xv -cmap' and 'gimp &'.

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Both will Need Debugging



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If it all works... you party.



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The next big thing: The BLT



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The next next big thing: MRO

- 10 elements
- 1.4m class telescopes
- Reconfigurable array in a Y shape
- B min approx 6m, B max approx 400m
- RIJHK operation
- Vacuum relay and delay lines
- Separate optical and near-IR beam combiners
- Separate science and fringe-tracking beam combiners
- First light (whatever that means) 2008

So that's what an interferometer looks like.

- They do tend to look the same.
- Should we continue to build them like this? (See: D. F. Buscher and C. A. Haniff. Interferometric fitness and the large optical array. In Interferometry for Optical Astronomy II, volume 4838 of Proc. SPIE.)

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Optical Long Baseline Interferometry Newsletter

- <http://olbin.jpl.nasa.gov>
- Contains links to all existing and proposed optical/IR interferometer projects.
- News
- Papers and preprint information
- Upcoming meetings
- Contact information
- Translations of selected papers
- List of PhD and Masters theses
- Photographs and resources
- Job listings

