



Project Update:

MYSTIC*

Michigan Young STellar Imager at CHARA

John D. Monnier, Jean-Baptiste le Bouquin, Narsi Anugu, Stefan Kraus, Jacob Ennis, Ben Setterholm, Cyprien Lanthermann,

IPAG: Laurent Jocou

CHARA: Theo ten Brummelaar

* Funding thanks to National Science Foundation



Observatoire
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Science Motivation

I. Imaging Inner disks of Young Stellar Objects

	MWC275 (Herbig Ae)	V1295 Aql (Herbig Be)	SU Aur (T Tauri)
J/H/K uncorrelated	6.2 / 5.5 / 4.8	7.2 / 6.6 / 5.9	7.2 / 6.6 / 6.0
Visibility (V) on longest baseline	0.3? / 0.2 / 0.1	0.5? / 0.3 / 0.2	0.6? / 0.5? / 0.4
J/H/K correlated	7.5 / 7.2 / 7.3	8.0 / 7.9 / 7.6	7.8 / 7.3 / 7.0

II. Precision Closure Phases (exoplanets)

III. Polarization to detect scattered light

IV. Spectro-Interferometry (Br-gamma)

Integration with MIRCx for J+H+K simultaneous observing (+visible?)



Instrument Architecture

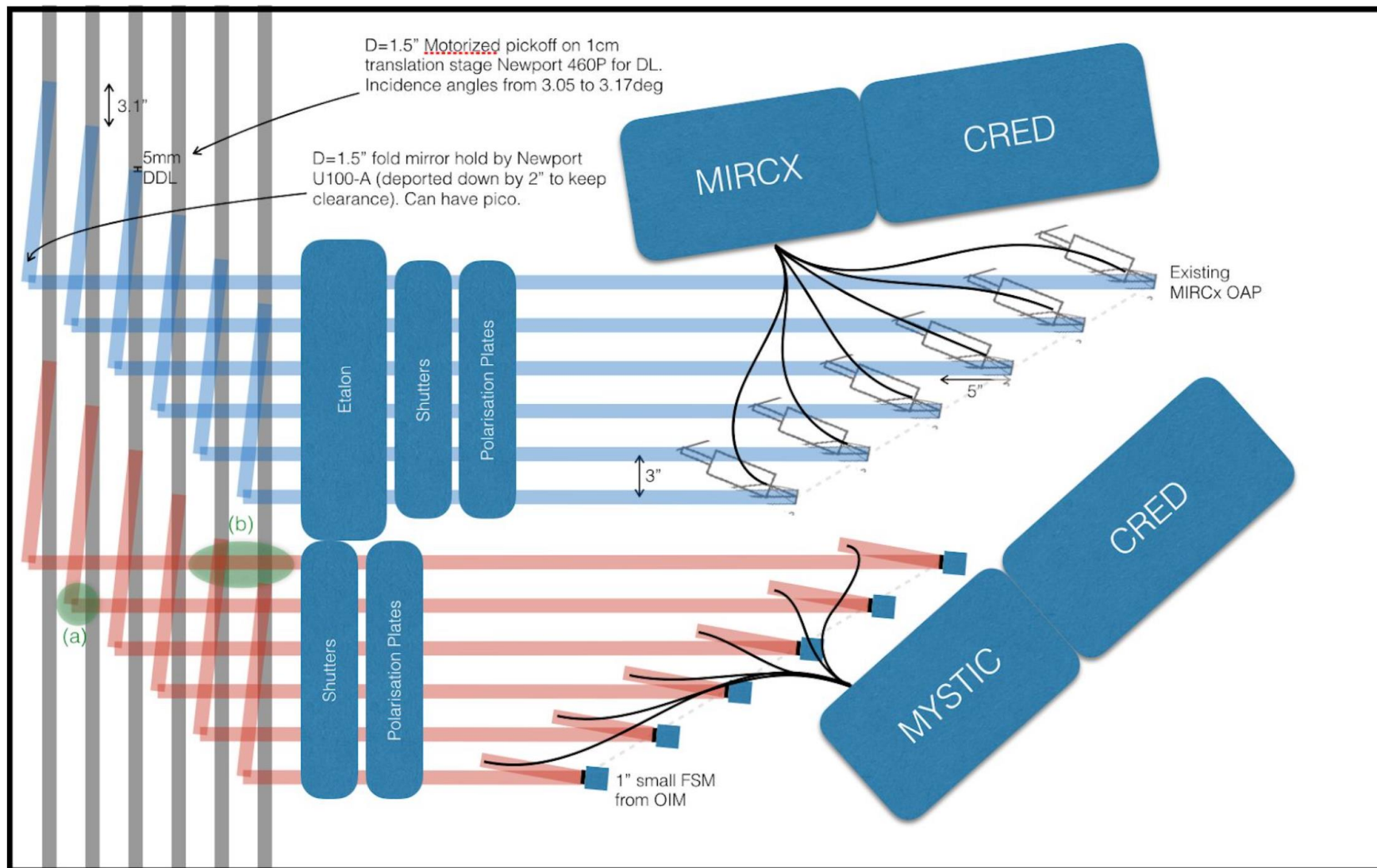
- 1.9-2.4 micron sensitivity
 - Assumes CHARA AO working before commissioning
- CRED-One camera + 200K cryogenic dewar
- 4 beam mode for high sensitivity
 - Using spare GRAVITY IO chip
 - No cross talk
- 6 beam mode for snapshot imaging
 - Using “classic” MIRC-style combiner
- Wollaston mode for polarization experiments
- Many options for grisms for spectroscopy



Team

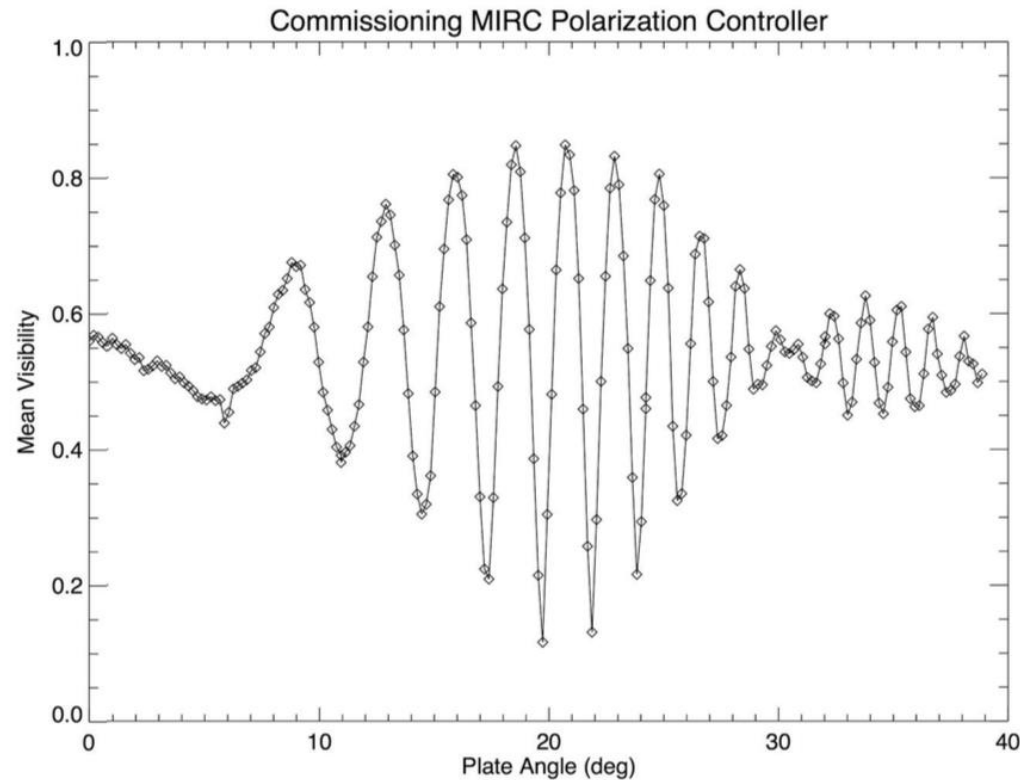
- John Monnier (PI, UM)
- Jean-Baptiste Le Bouquin (UM/IPAG)
- Narsi Anugu (Exeter)
- Stefan Kraus (Exeter)
- Ben Setterholm (UM graduate student)
- Jacob Ennis (UM undergraduate)
- Cyprien Lanthermann (IPAG grad student)
- IPAG: Laurent Jucou
- CHARA: Theo ten Brummelaar ++

Layout on "MIRC Table"



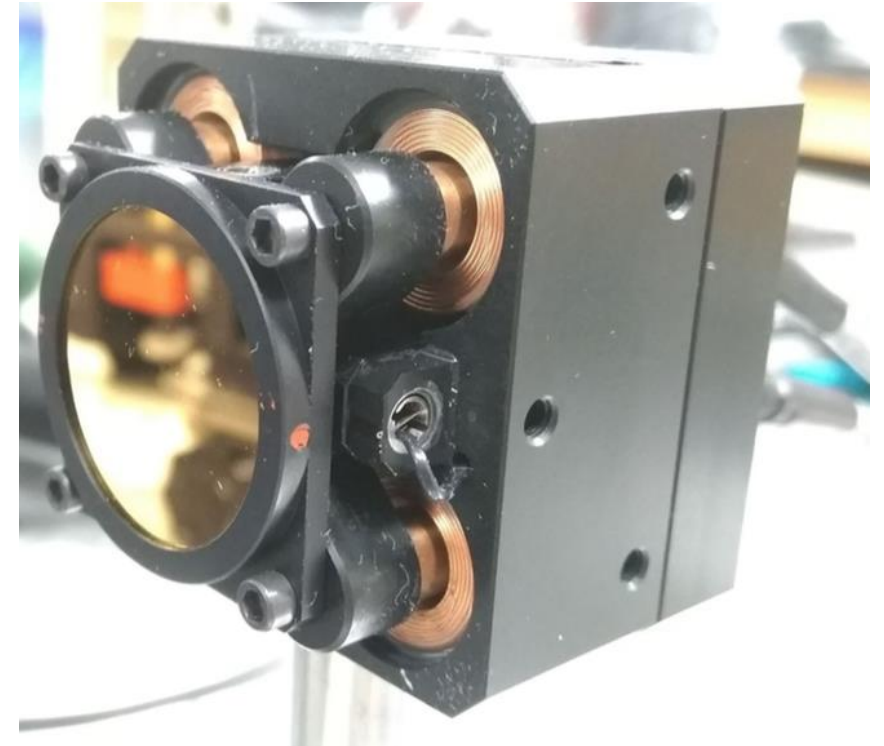
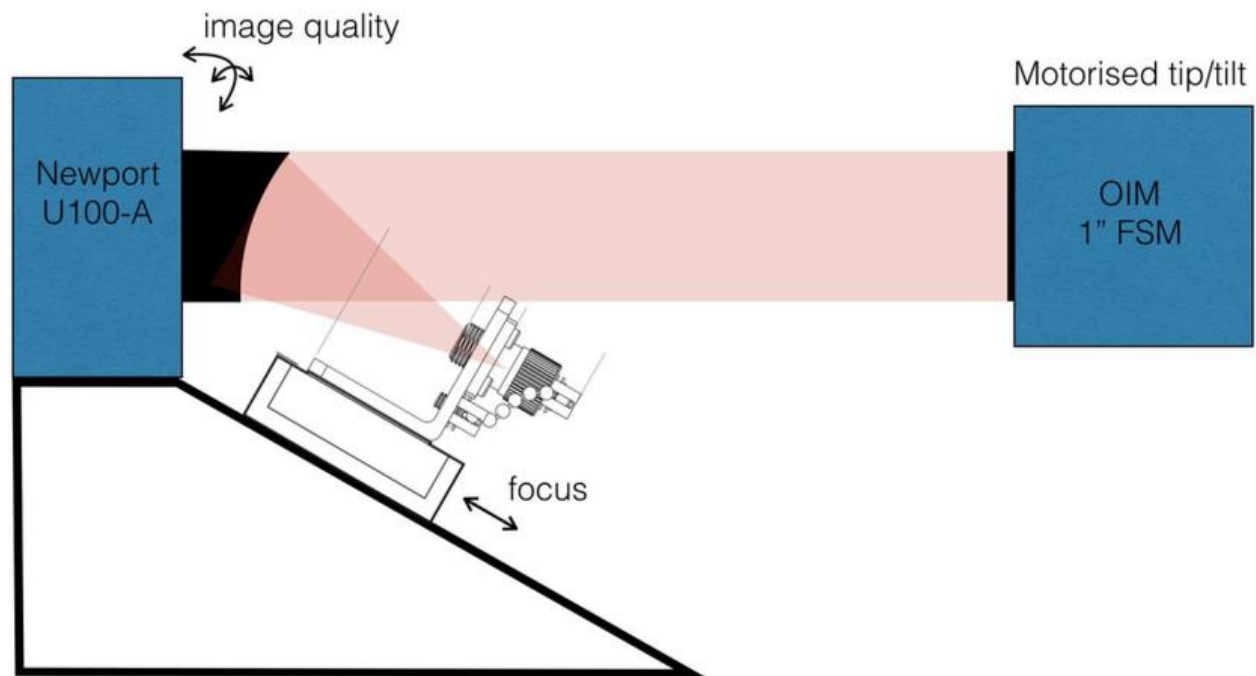
Warm optics (detail)

- New Polarization controller
 - Based on Lazareff et al. LiNbO₃ plates
 - Tested for MIRCx already



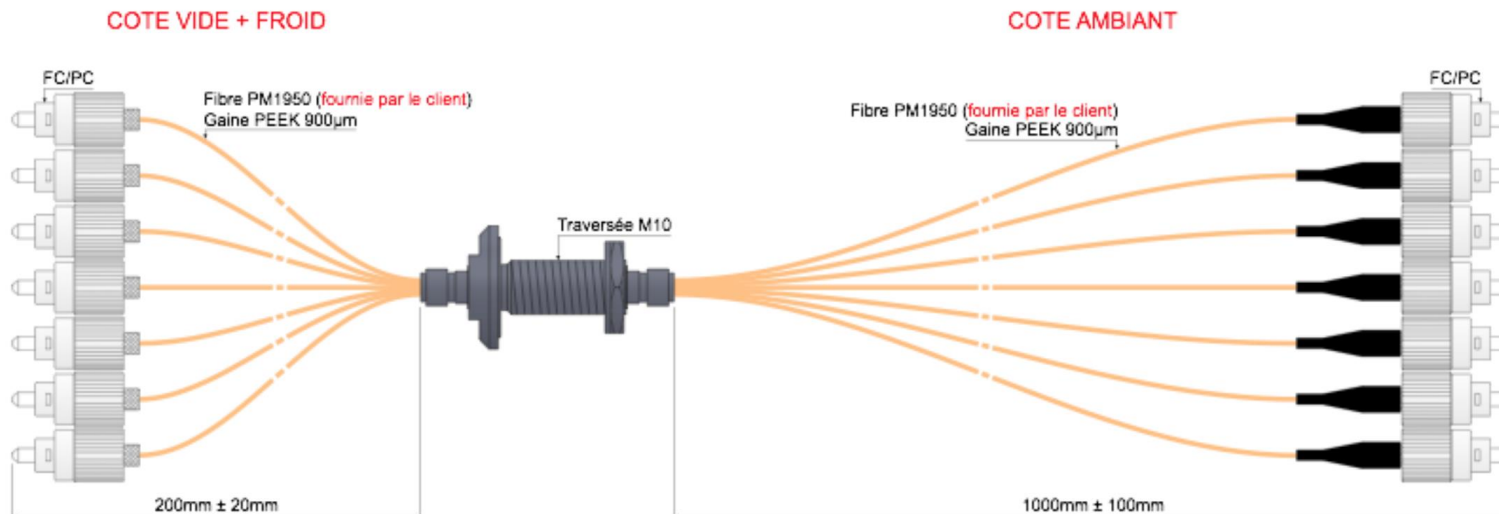
Warm optics (detail)

- Fiber injection using OTS components

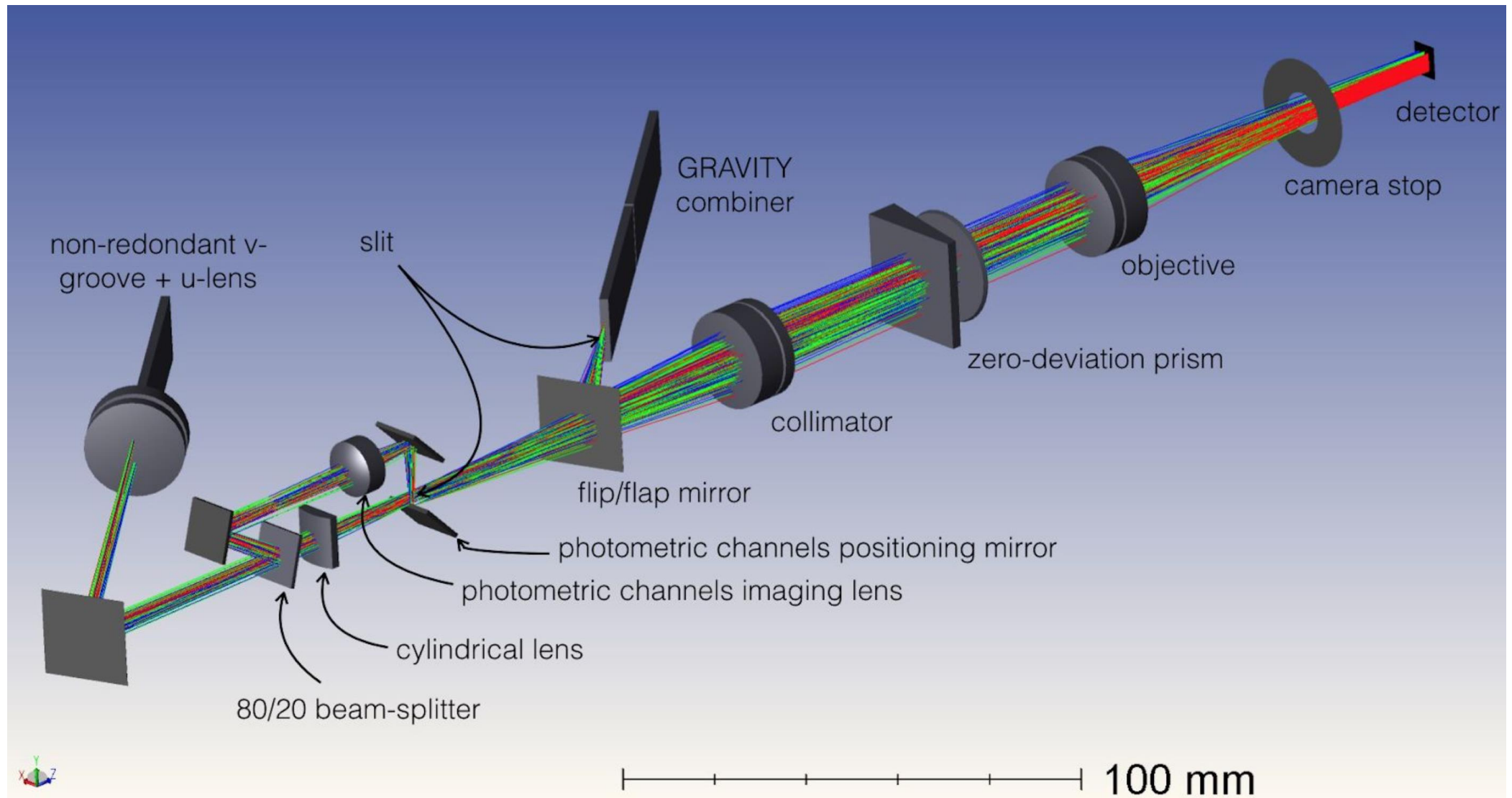


Single-mode IR Fibers

- Nufern PM1950
 - Low-OH silica fibers
 - 7%/m loss at 2.2 μ m, 15%/m at 2.37 μ m
 - Less expensive and robust than fluoride fibers
 - NA 0.20, compatible w/GRAVITY NA 0.19
- Fibrer Feedthrough into Dewar



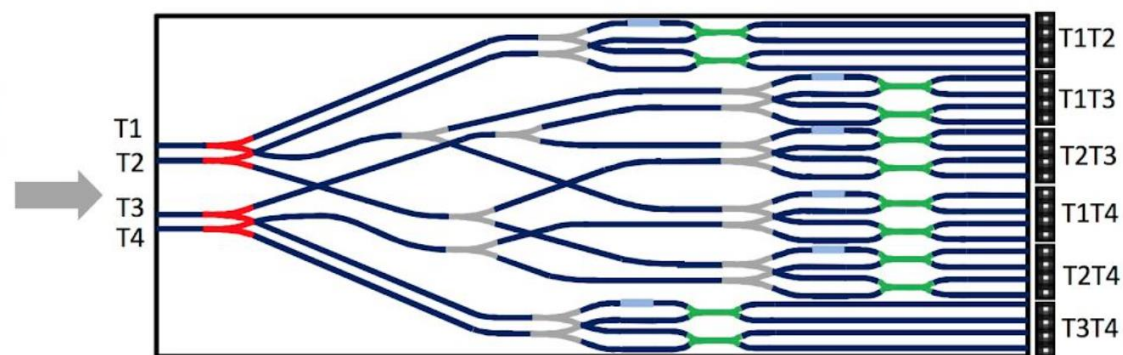
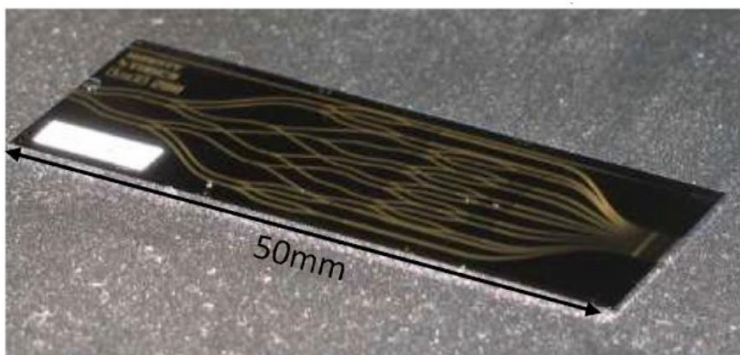
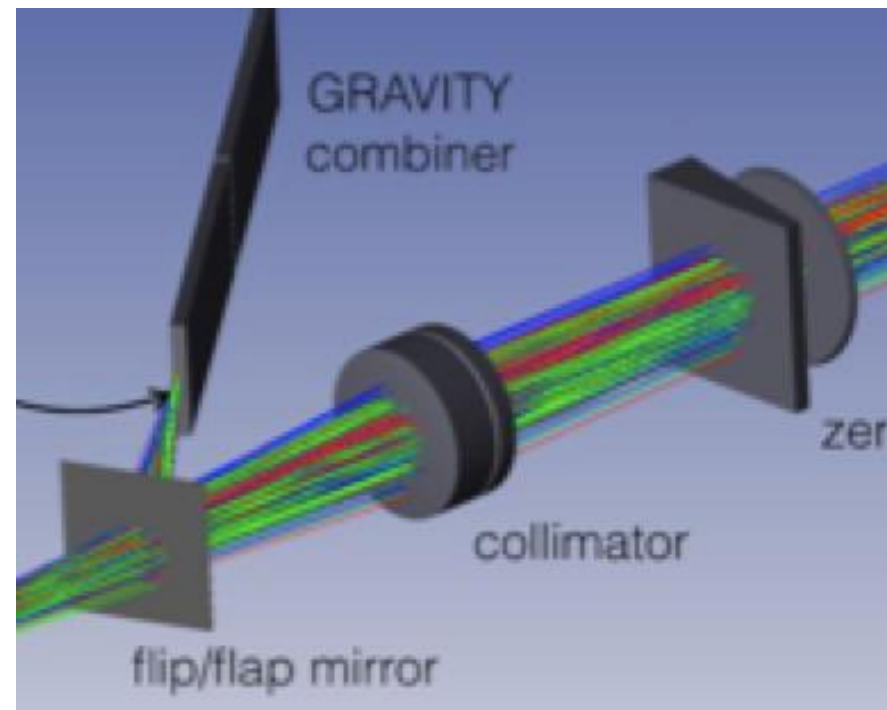
Cold optics Overview



Two cold combiners

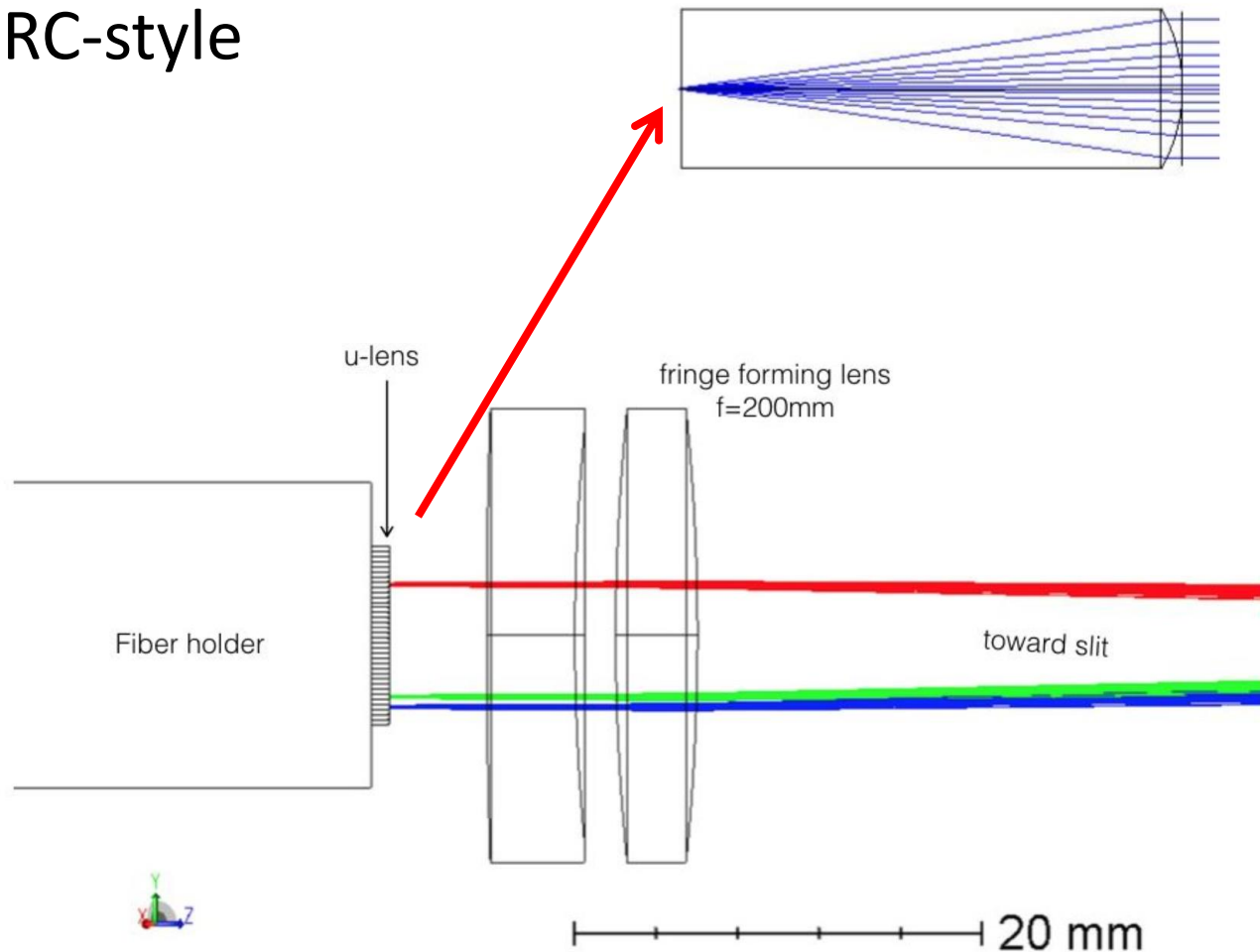
- GRAVITY

- 4 beams = 6 fringes
- Each fringe has 4 outputs ABCD => 24 outputs
- 180 mu separation



Two cold combiners

- MIRC-style



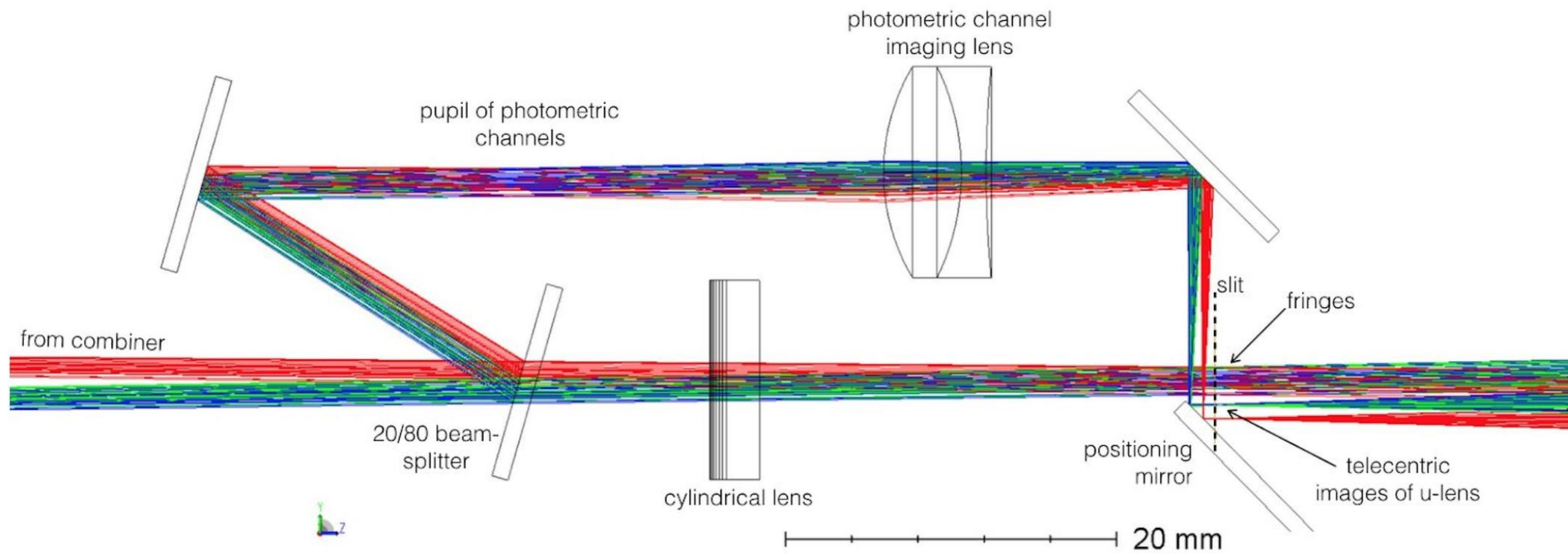
Custom-thinned
Microlens array
Glued to vgroove





Two cold combiners

- MIRC-style
 - New approach to photometric channels
 - Reimage microlens array itself onto slit

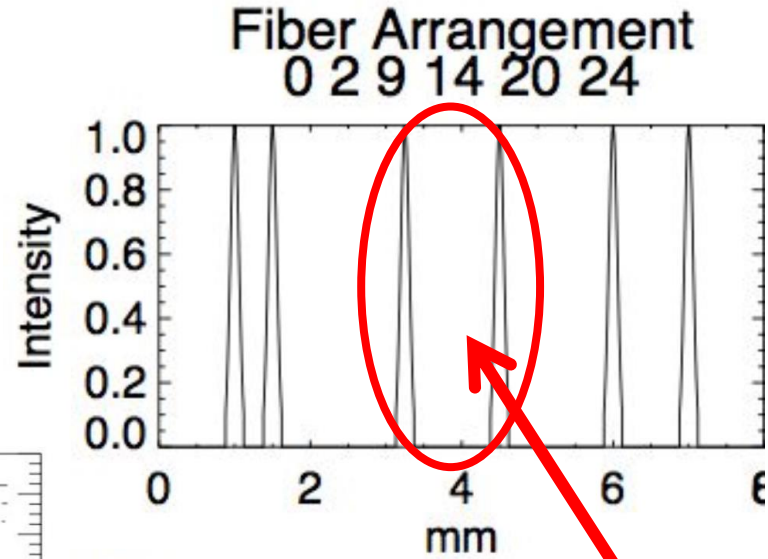




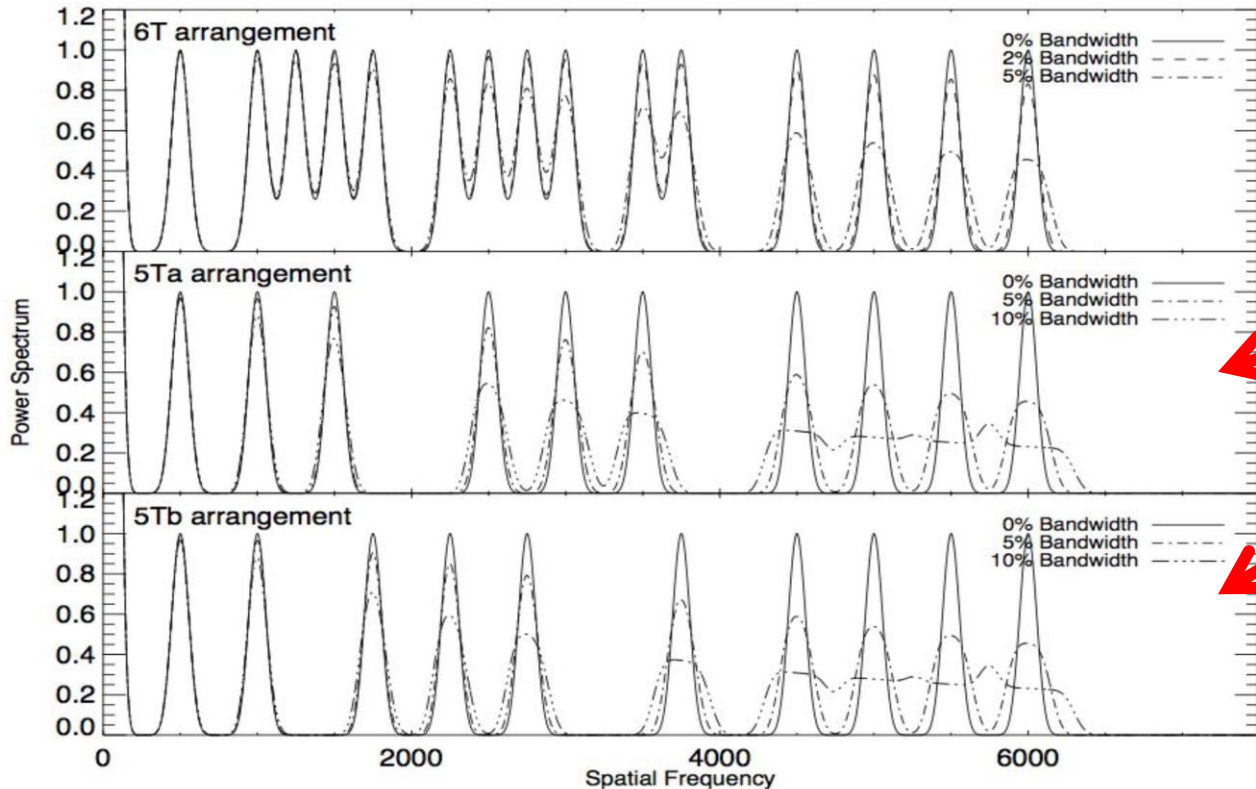
Two cold combiners

- MIRC-style
 - New pattern

Cross-talk resistant power spectra

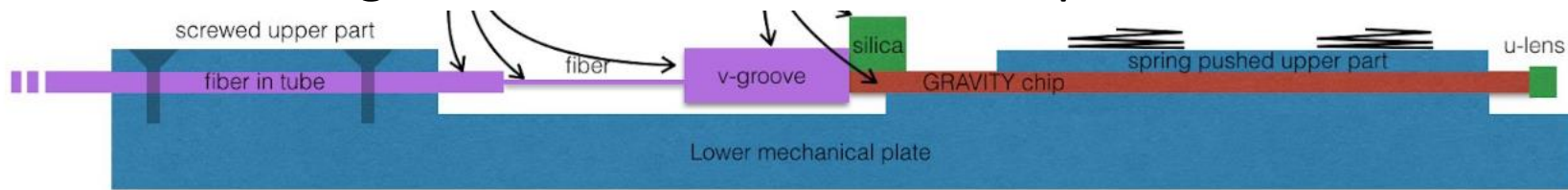


Remove an inner fiber
For cross talk resistance!



Some Challenges*

- Length-matching of fibers
 - 2mm -> 5% visibility loss
 - Mitigation: use glass wedges in front to remove differential OPD
- Cryogenic Mounting and IO/fiber interfaces
 - Learning from GRAVITY and IPAG expertise



- Mechanical Design of 200K Dewar
 - We want 200K to be the cold plate temperature, not dewar price
- Accumulation of Delays
 - If we missing Summer 2019 commissioning window, then big problem.



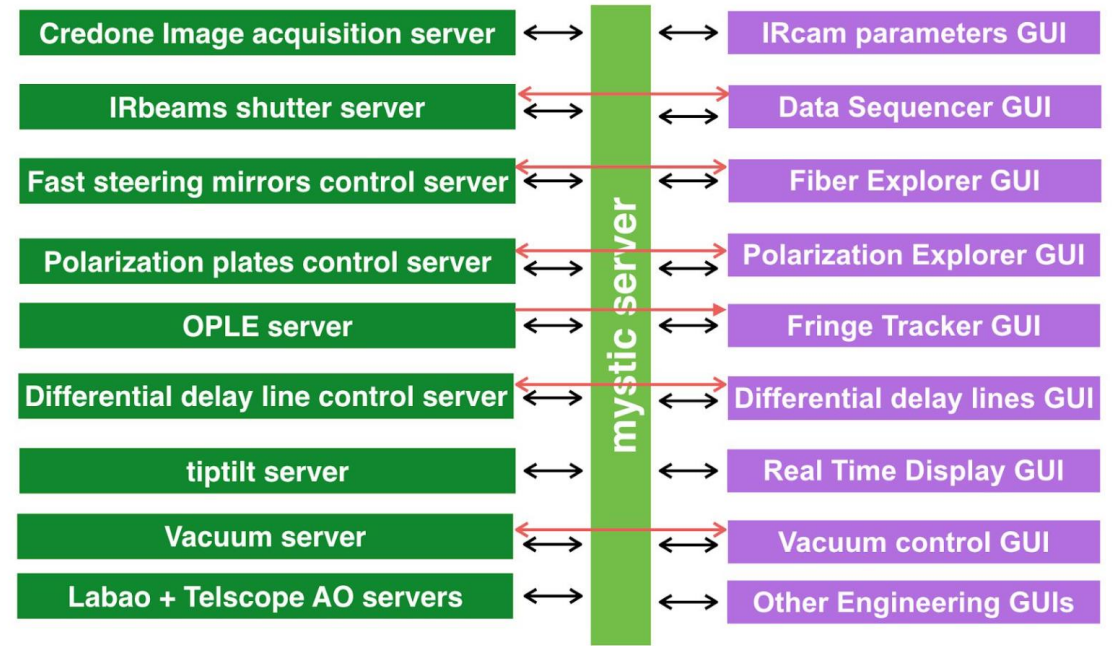
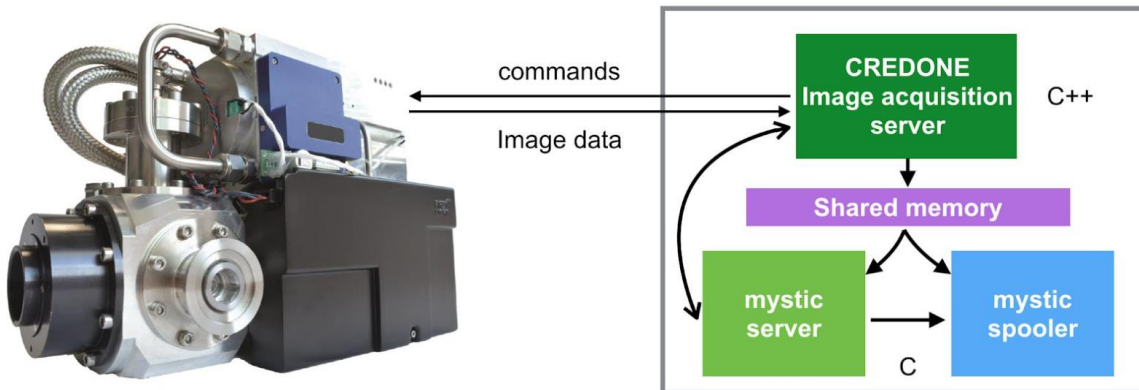
Detector

- See other talks by Stefan and Cyprien on MIRCx results and camera performance analysis



Software

- Based on original MIRC realtime code modified for CRED-ONE
- Deployed first on MIRCx (working already)
- Re-writing all GUIs to be CHARA-compatible
- Unbelievable job by Narsi Anugu so far



./mircx_gdt_gtk --> mircx_server (on mircx)

beam order, pops	cart pos, error	offset sent	step size	S1	S2	E1	E2	W1	W2					
S1 3 1 MAN FT	-0.00m -19nm	<<< <	0.000 >>>	0.005	Loop-	Loop+	0	S1	-	x	x	x	x	x
S2 2 2 MAN FT	0.00m 0nm	<<< <	0.043 >>>	0.005	Loop-	Loop+	0	S2	16.5	-	x	x	x	x
E1 4 1 MAN FT	0.00m -17nm	<<< <	0.121 >>>	0.005	Loop-	Loop+	0	E1	2.4	2.0	-	x	x	x
E2 5 1 MAN FT	0.00m 0nm	<<< <	0.085 >>>	0.005	Loop-	Loop+	0	E2	1.8	0.2	1.3	-	x	x
W1 1 4 MAN FT	0.00m 4nm	<<< <	0.123 >>>	0.005	Loop-	Loop+	0	W1	1.5	1.8	3.0	1.0	-	x
W2 6 5 MAN FT	-0.00m -8nm	<<< <	0.000 >>>	0.005	Loop-	Loop+	0	W2	0.3	2.0	16.6	2.7	1.2	-

Search Threshold 3.0 | 3.00

CARTS TRACK				CARTS OFF				FRINGE LOCK				CLEAR MATRIX			
S1	S2	S1 E1	S1 E2	S1 W1	S1 W2	S2 E1	S2 E2	S2 W1	S2 W2	E1 E2	E1 W1	E1 W2	E2 W1	E2 W2	W1 W2
OPD:	1.6	12.0	18.6	-1.8	-22.7	7.3	21.3	-4.5	-3.8	-1.5	4.2	-1.2	-16.6	-9.8	-3.4
SNR:	247.7	36.5	26.4	21.9	3.9	29.3	2.7	26.7	30.3	18.8	45.3	249.7	15.0	41.2	18.5
THRESHOLD:	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0

GET SEND 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0

CALC ALL CALC CALC CALC CALC CALC CALC CALC CALC CALC CALC CALC CALC CALC CALC

HD_29246 HA: 08 29 21.725 SEEING -nan+-nan cm

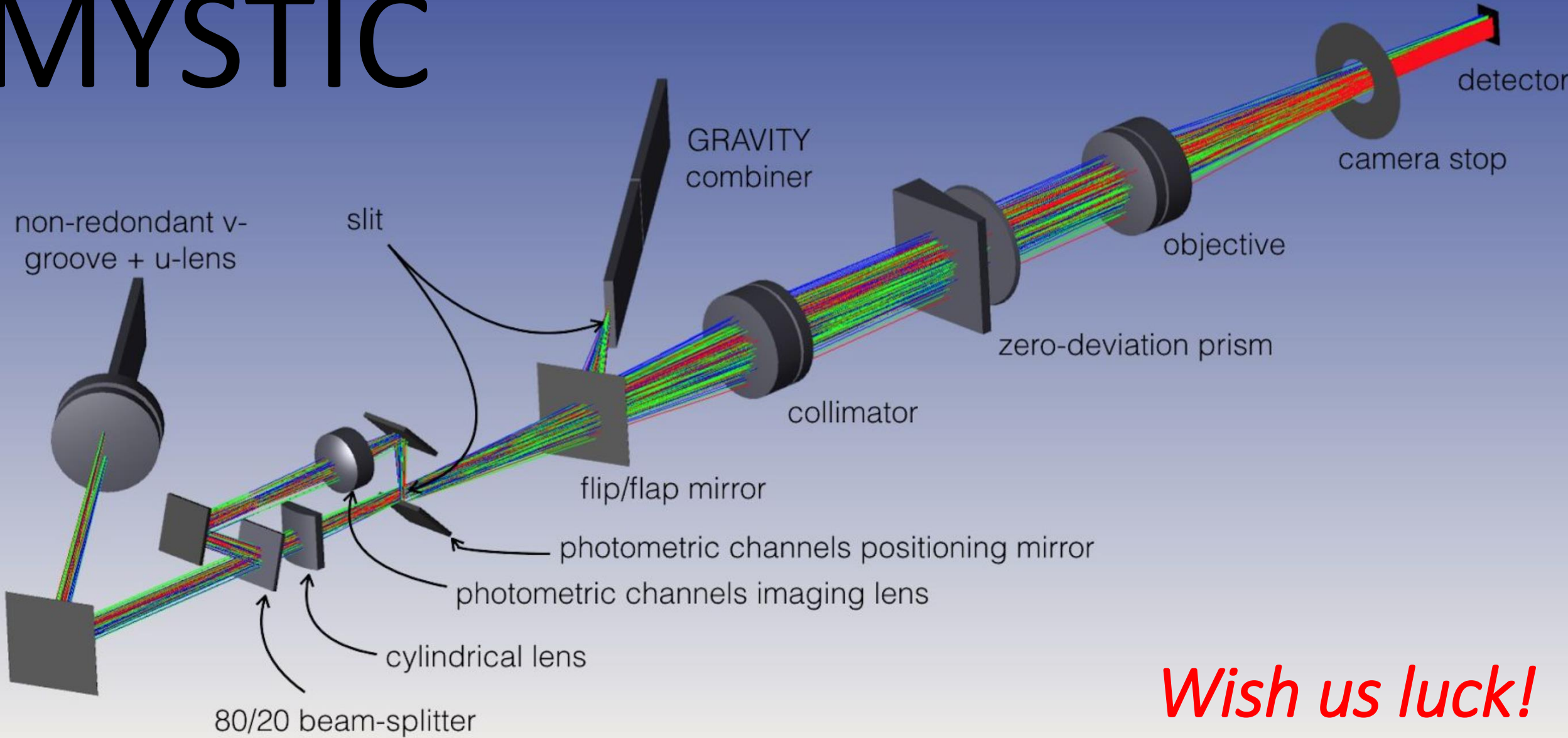
PING MIRCX PING OPLE REOPEN QUIT Receive pyconfig



Timeline*

Date	Milestone
2018 March	MYSTIC Design Review
2018 April	Prototype new photometric channels (for MIRCx)
2018 Aug	Final Design of 200K Dewar – place order
2018 Fall	Build “WARM” mystic in lab
2019 Jan	Receive dewar and move system inside
2019 Feb-Mar	Test system in Michigan
2019 May	On-sky commissioning at CHARA
2019 July	End of grant officially (JB goes back to France)
2020 July	All monies must be spent by then.

MYSTIC



Wish us luck!

100 mm





Backups



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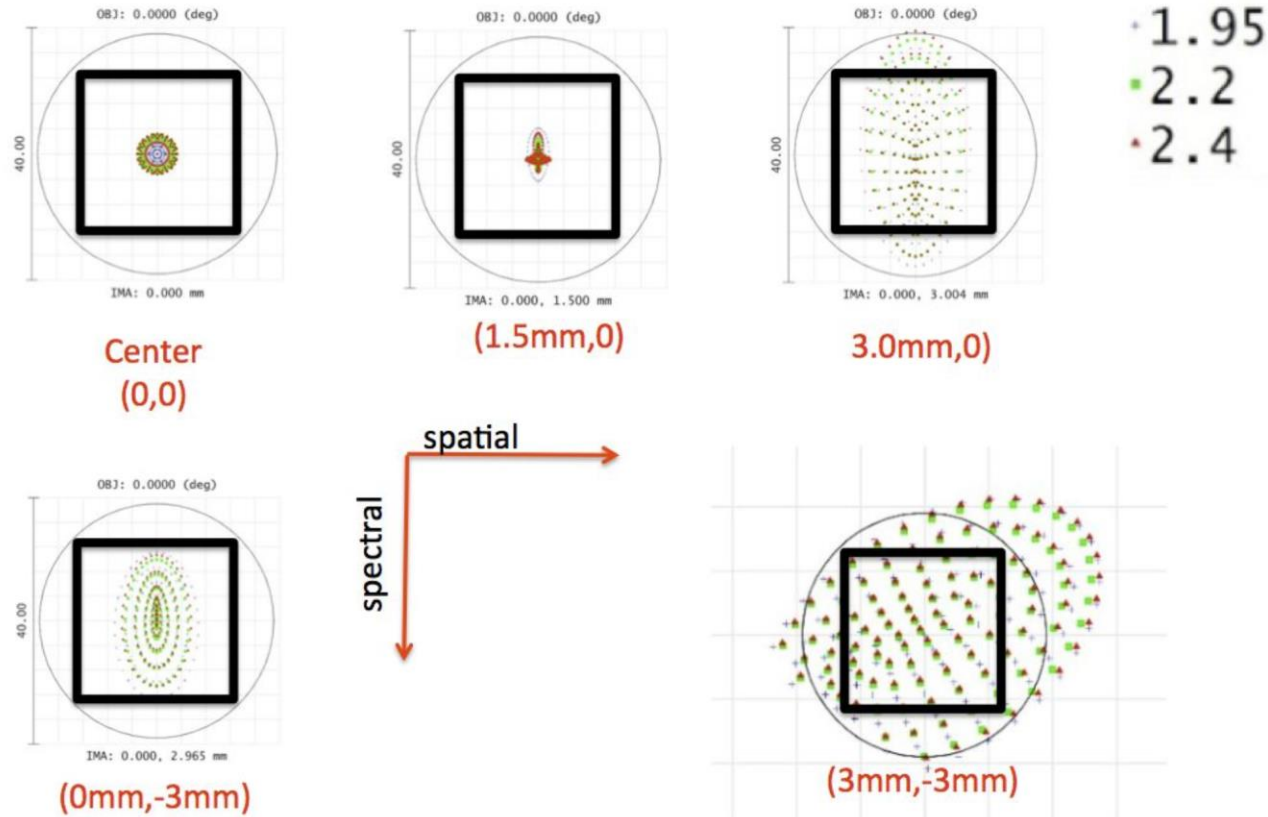


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Spectrograph

- Geometrical Ray Trace
 - Spot diagrams



Spectrograph

- Physical Propagation Calculation
 - Fiber -> detector
 - Check vignetting at awkwardly-placed cold stop

Vignetting at Camera Stop

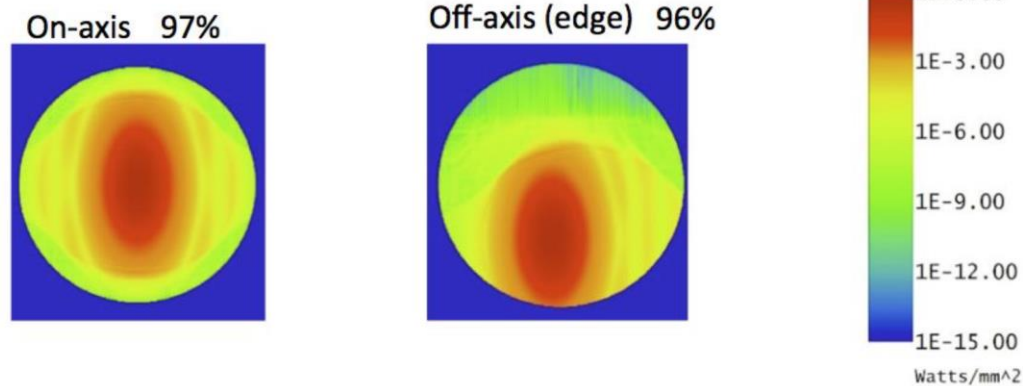
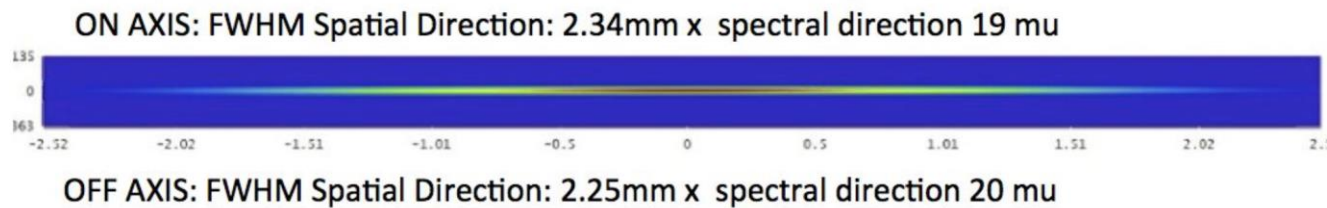


Image Quality (2.2μ)





Project Status

- Year 1: 2015 Aug-2016

- Funding starts (National Science Foundation)
- Narsi Anugu (Exeter) leads joint MIRCX software DAQ
- UM undergrads clone CHARA stepper motor control system
- CRED-ONE negotiations and contract

- Year 2: 2016Aug-2017Jul

- Recruited graduate student Ben Setterholm
- Jacob Ennis leads design/build of polarization controllers
- Fiber testing and selection
- CRED-one acceptance testing
- MIRCx on-sky commissioning

- Year 3: 2017Aug-2018Jul

- Jean-Baptiste le Bouquin starts at UM for 2-year work
- Finalize optical design work
- All new gtk guis
- MYSTIC project design review (this Wednesday)