



MIRCx+MYSTIC as a Fringe Tracker

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MIRCx

- ERC-funded project to equip MIRC with SELEX/SAPHIRA-based detector
- Other improvements in optical design to optimize sensitivity (new fibers, V-groove) and accuracy (polarisation control; reduced cross-talk)
- Simultaneous J+H observations
- Options for high-spectral resolution mode and observations in polarized light



MYSTIC

- NSF-funded project to build new cryogenic instrument operating in K-band
- Also based on SELEX/SAPHIRA-based detector
- Different optical designs under discussion, incl.
 - MIRC-like All-in-One combination
 - 3x4T GRAVITY IO combiners
 - New 6T IO combiner from ANU
- Options for high-spectral resolution mode and observations in polarized light

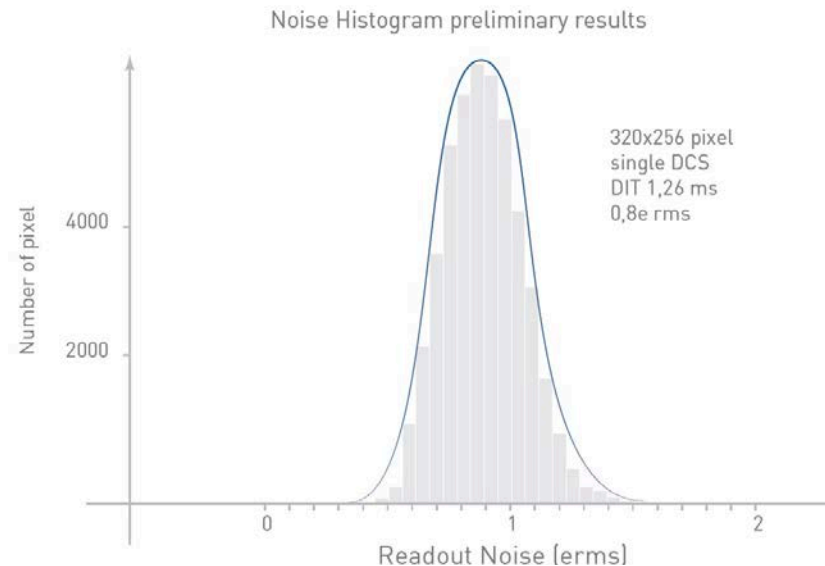


SELEX/SAPHIRA detector

Current PICNIC detector:
Read-noise 17.7e⁻ (single read, 300 Hz)

→ SAPHIRA: read-noise (0.8 e⁻, 3507 Hz)

→ Read-noise reduction by factor ~20



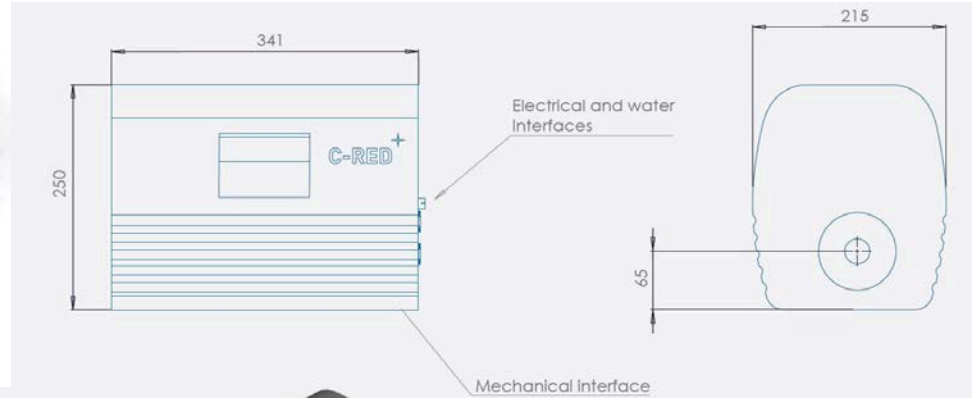
Test measurement	Result	Unit
Maximum speed	3507	FPS
Mean Dark + Readout Noise at 3500 fps and gain ~ 30	<1	e-
Quantization	16	bit
Detector Operating Temperature	80	K
Peak Quantum Efficiency from 1.3 μm to 2.5 μm	>70	%
Operability ± 30%	99.3	%
Image Full well capacity at gain X1, 3500 fps	200 000	e-
Excess noise Factor F	1.25	n/a

Credit: First Light Imaging



Observatoire de la CÔTE d'AZUR

SELEX/SAPHIRA detector



- Pulse tube cooling (vibration-free)
- 1 cold filter possible

Credit: First Light Imaging



MIRCx+MYSTIC

- Preliminary timescale for commissioning (earliest times):
2017 (MIRCx), 2019 (MYSTIC)
- MIRCx and MYSTIC will be designed to act as fringe-tracker for each other
- We build on MIRC design, experience, and software



Group-delay tracking

- Group-delay tracking (10 Hz, max. 30 Hz) implemented as standard MIRC observing mode, was also used to support VEGA

The screenshot shows the 'gdtControl2' software interface. On the left, there are six sections for delay lines (S1, S2, E1, E2, W1, W2), each with 'ZERO', 'STEP SIZE', and 'LOOP' controls. The right side features a table of baselines with columns for 'BASELINES', 'OPD', 'WEIGHT', 'THRESHOLD', and 'LOCK'. Below the table are buttons for 'GET FRINGE INFO', 'START LOOP', 'LOCK FRINGES', 'SEND GDT INFO', 'SEARCH THRESH. FACTOR', 'CALC ALL', and 'UPDATE THRESH'. At the bottom right is a correlation matrix.

BASELINES	OPD	WEIGHT	THRESHOLD	LOCK
W1 S2	-9	143	9	<input checked="" type="checkbox"/>
W1 S1	-16	61	8	<input checked="" type="checkbox"/>
W1 E1	-25	0	5	<input type="checkbox"/>
W1 E2	2	3	4	<input checked="" type="checkbox"/>
W1 W2	-6	302	5	<input checked="" type="checkbox"/>
S2 S1	-9	190	10	<input checked="" type="checkbox"/>
S2 E1	26	0	10	<input type="checkbox"/>
S2 E2	9	6	5	<input type="checkbox"/>
S2 W2	1	226	4	<input checked="" type="checkbox"/>
S1 E1	25	0	7	<input type="checkbox"/>
S1 E2	12	5	5	<input checked="" type="checkbox"/>
S1 W2	7	72	8	<input checked="" type="checkbox"/>
E1 E2	31	2	7	<input type="checkbox"/>
E1 W2	13	1	10	<input type="checkbox"/>
E2 W2	-6	71	5	<input checked="" type="checkbox"/>

	S1	S2	E1	E2	W1	W2
S1	-	-3.336	0.953	6.464	1.789	-0.988
S2	19.1	-	-2.283	3.128	5.125	-4.324
E1	0.0	0.0	-	5.405	2.824	-2.047
E2	1.1	1.4	0.3	-	8.227	-7.452
W1	7.2	14.5	0.2	0.7	-	0.801
W2	8.6	45.8	0.1	14.4	55.9	-



Group-delay tracking

- Group-delay tracking (10 Hz, max. 30 Hz) implemented as standard MIRC observing mode, was also used to support VEGA

gdtControl2

DELAY LINE S1: beam 3 use this tel reference tel

ZERO << < -1.447 > >>

STEP SIZE 0.008 LOOP - LOOP + threshold check

DELAY LINE S2: beam 2 use this tel reference tel

ZERO << < 3.279 > >>

STEP SIZE 0.008 LOOP - LOOP + threshold check

DELAY LINE E1: beam 4 use this tel reference tel

ZERO << < -5.812 > >>

STEP SIZE 0.008 LOOP - LOOP + threshold check

DELAY LINE E2: beam 5 use this tel reference tel

ZERO << < -4.007 > >>

STEP SIZE 0.008 LOOP - LOOP + threshold check

DELAY LINE W1: beam 1 use this tel reference tel

ZERO << < 0.000 > >>

STEP SIZE 0.008 LOOP - LOOP + threshold check

DELAY LINE W2: beam 6 use this tel reference tel

ZERO << < -2.786 > >>

STEP SIZE 0.008 LOOP - LOOP + threshold check

QUERY TIPTILT GET OFFSETS SLEEP TIME 0.5

CLOSE

BASELINES	OPD	WEIGHT	THRESHOLD	LOCK
W1 S2	0	635	20	CALC THRESH <input checked="" type="checkbox"/>
W1 S1	5	139	12	CALC THRESH <input checked="" type="checkbox"/>
W1 E1	0	617	6	CALC THRESH <input checked="" type="checkbox"/>
W1 E2	1	59	7	CALC THRESH <input checked="" type="checkbox"/>
W1 W2	0	791	10	CALC THRESH <input checked="" type="checkbox"/>
S2 S1	10	31	26	CALC THRESH <input checked="" type="checkbox"/>
S2 E1	0	1748	11	CALC THRESH <input checked="" type="checkbox"/>
S2 E2	0	445	5	CALC THRESH <input checked="" type="checkbox"/>
S2 W2	0	1043	4	CALC THRESH <input checked="" type="checkbox"/>
S1 E1	-3	138	8	CALC THRESH <input checked="" type="checkbox"/>
S1 E2	-2	197	7	CALC THRESH <input checked="" type="checkbox"/>
S1 W2	-3	106	6	CALC THRESH <input checked="" type="checkbox"/>
E1 E2	0	13593	7	CALC THRESH <input checked="" type="checkbox"/>
E1 W2	0	6375	40	CALC THRESH <input checked="" type="checkbox"/>
E2 W2	0	4111	22	CALC THRESH <input checked="" type="checkbox"/>

GET FRINGE INFO START LOOP SEARCH THRESH. FACTOR 3 CALC ALL

LOCK FRINGES SEND GDT INFO UPDATE THRESH

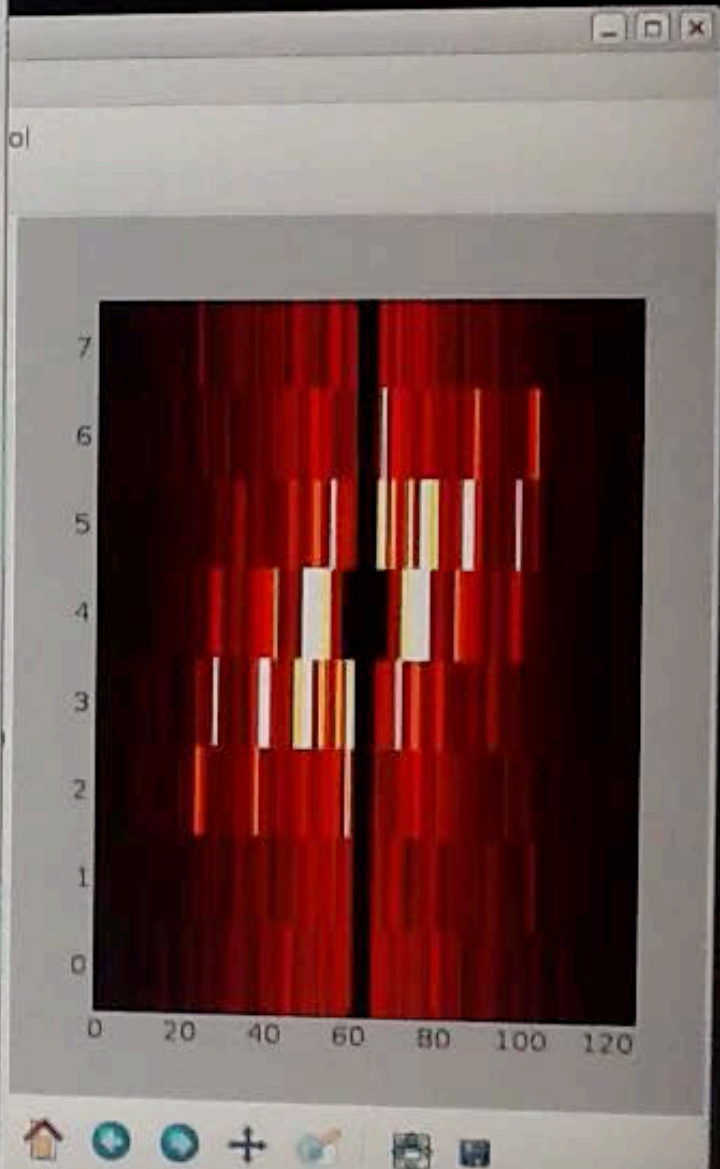
	S1	S2	E1	E2	W1	W2
S1	-	-4.725	-4.365	-2.560	-1.447	-1.339
S2	0.4	-	-9.091	-7.286	3.279	-6.065
E1	5.6	49.4	-	1.805	-5.812	3.026
E2	9.0	28.0	641.7	-	-4.007	1.221
W1	3.8	10.6	30.9	2.7	-	-2.786
W2	5.9	69.7	53.1	59.7	24.3	-

S1	4	37	5	CALC THRESH	<input checked="" type="checkbox"/>
E1	9	61	7	CALC THRESH	<input checked="" type="checkbox"/>
E2	5	20	20	CALC THRESH	<input checked="" type="checkbox"/>
W2	7	14	9	CALC THRESH	<input checked="" type="checkbox"/>
S2	18	93	20	CALC THRESH	<input checked="" type="checkbox"/>
E1	7	39	5	CALC THRESH	<input checked="" type="checkbox"/>
E2	5	7	4	CALC THRESH	<input checked="" type="checkbox"/>
W2	4	3	6	CALC THRESH	<input checked="" type="checkbox"/>
E1	12	5	2	CALC THRESH	<input checked="" type="checkbox"/>
E2	7	23	6	CALC THRESH	<input checked="" type="checkbox"/>
W2	2	8	6	CALC THRESH	<input checked="" type="checkbox"/>
E2	4	57	20	CALC THRESH	<input checked="" type="checkbox"/>
W2	7	9	6	CALC THRESH	<input checked="" type="checkbox"/>
W2	9	34	20	CALC THRESH	<input checked="" type="checkbox"/>

SEARCH THRESH. FACTOR:

Clear Matrix

	S1	S2	E1	E2	W1	W2
031.3291.33/1	S1	6.612	2.323	-1.478	-0.702	1.327
047.947.94/7	S2	0.8	8.938	6.132	5.908	7.939
001.100-10/	E1	1.0	8.0	-3.806	-3.030	-0.998
11/2.81/2.81/2	E2	1.8	2.8	2.9	0.778	2.809
23/2.03/2.03/2	W1	3.8	3.7	4.3	0.6	2.028
	W2	0.8	0.1	0.7	0.9	0.8



12Nov06/mirc0325.fits
 Star: HD_14055 at UT 3:12:14.0000 DATA

12Nov06/mirc0326.fits
 Star: HD_14055 at UT 3:12:20.0000 DATA
 999 out of 1000 Frames!

```

Received Request OF...Received Request OF...Sending 0.001325 to DL 0
Sending 0.007935 to DL 1
Sending -0.001003 to DL 2
Sending 0.002803 to DL 3
Sending 0.002027 to DL 4
Received Request OF...numberCohere...
  
```



Group-delay tracking

- First implementation could re-use MIRC coherencing code, with one instrument acting as FT
- Goal is to implement global MIRCx+MYSTIC coherencing code, that uses fringe detections in any band (J/H/K) for group-delay tracking
- MIRCx: Read noise-reduction and improvements in optics should push sensitivity by 2-3 mag
- Allows for coherent integration of differential phase in spectral lines



Phase tracking

- SAPHIRA can go fast (3500 Hz), which could enable efficient phase-tracking ($\frac{1}{4}$ radian for bright stars?)
- Objective to have longer integrations for high-spectral resolution observations
(J-band: Pa β ; H-band: [FeII], ...; K-band: Br γ , CO)
- Implementation is not highest priority, but could reuse some CHAMP code



Application to visible light

Supporting visible instrument:

- MIRCx (J+H) obvious choice (closer in wavelength, more flux for blue objects), but ultimate goal is to track on any fringe detected in J/H/K
- Three 6T instruments need to be co-phased: MIRCx+MYSTIC+VIS (OPD between MIRCx and MYSTIC controlled internally)
- Longitudinal dispersion correctors → transmission problem in NIR?
- Group delay tracking: Compared to 3T (e.g. CLIMB), phase residuals should improve when going to 6T
- Phase tracking: Gains in V-band need to be quantified
- Coherent post-processing using FT information possible, if accurate timestamp information is kept on all instruments