Tuesday 2 Feb 1999

Optics and Instrument Layout:

i) KD's new photometer design - optical design (KD)
Kjetil can present his updated design for the photometer and we can pick over the bones.......throw fruit etc.....

ii) Implications for systems design (BMS)
I'll give a view from the systems end of what the new design will mean - what goes at what temp.; impact on the detectors etc etc...... plus I'll say something about the shutter and where it might go.

iii) Layout of the instrument and what goes where (BMS+ discussion)
Following (ii) I'd like to initiate a discussion on how the instrument might look; baffles enclosures.....

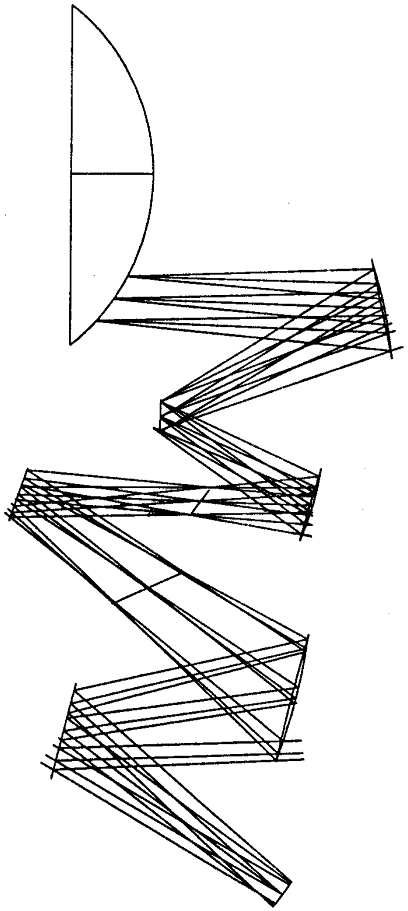
iv) Straylight control within FIRST and SPIRE - report on work on ESA contract (Tony Richards)
Tony is now well into the work for the APART model for ESA. I think it would be good for the rest of the team to have some visibility on this espec. as concerns changes in the telescope; sunshield etc...

v) Focal plane sharing and design of FIRST telescope (BMS, MJG?)
vi) Implications of field curvature for SPIRE optical design (KD)
We have to get back to ESA about this issue - has it gone away?

vii) Beam size for coherent and incoherent pixels (report by BMS + discussion)
I'll give a report on Martin's behalf and we can spend the rest of the day in confusion about what it all means......

viii) Workplan and goals for the next six months (BMS)
I'll present a skeleton of what we need to do and when but only to prompt a discussion.......

AZIMUTH 0.000 ELEVATION 0.000 SCALE 0.200 ID FIRST SPIRE PHOT (BOLPHT02) 150



01-FEB-99 16:54:59

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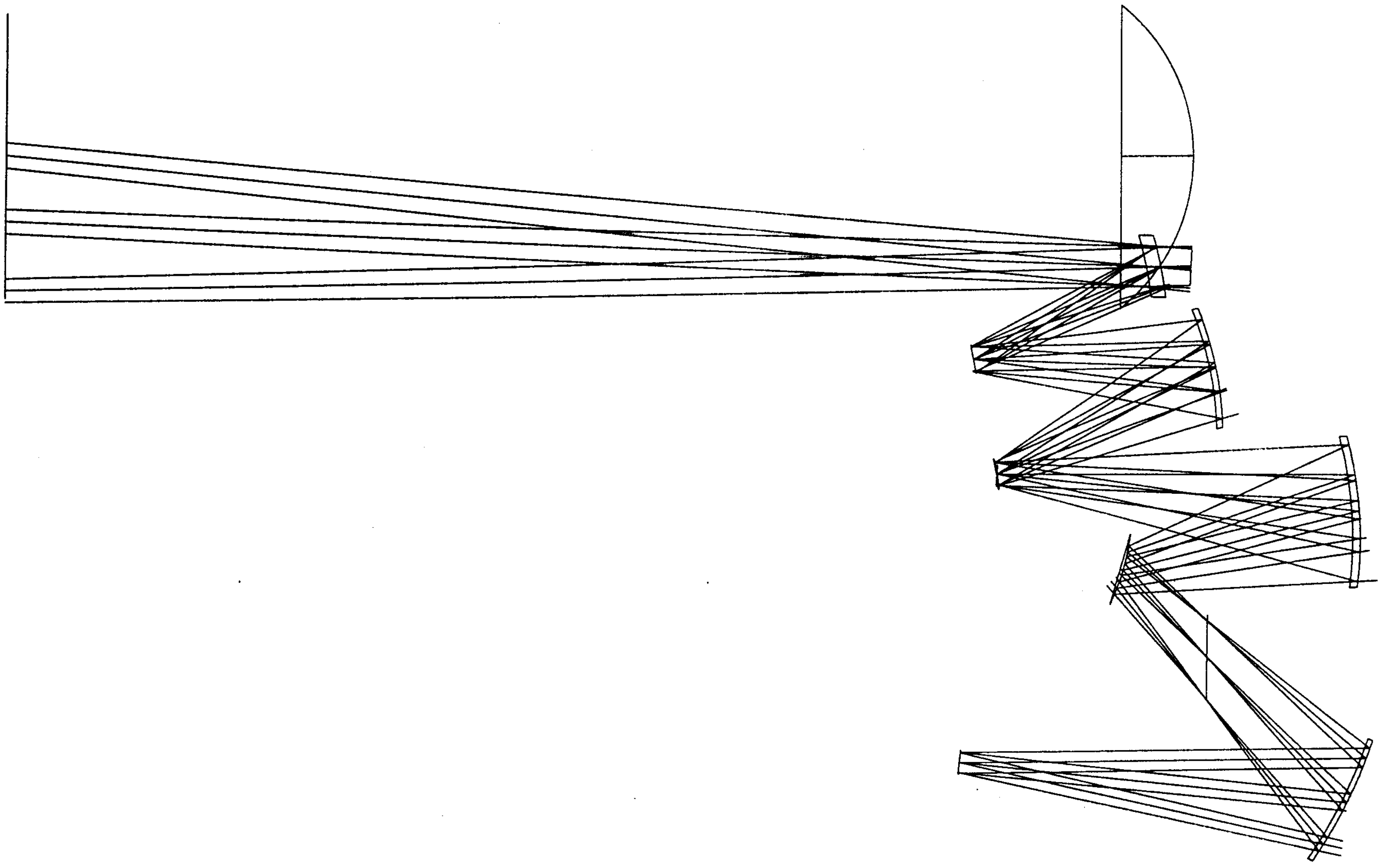

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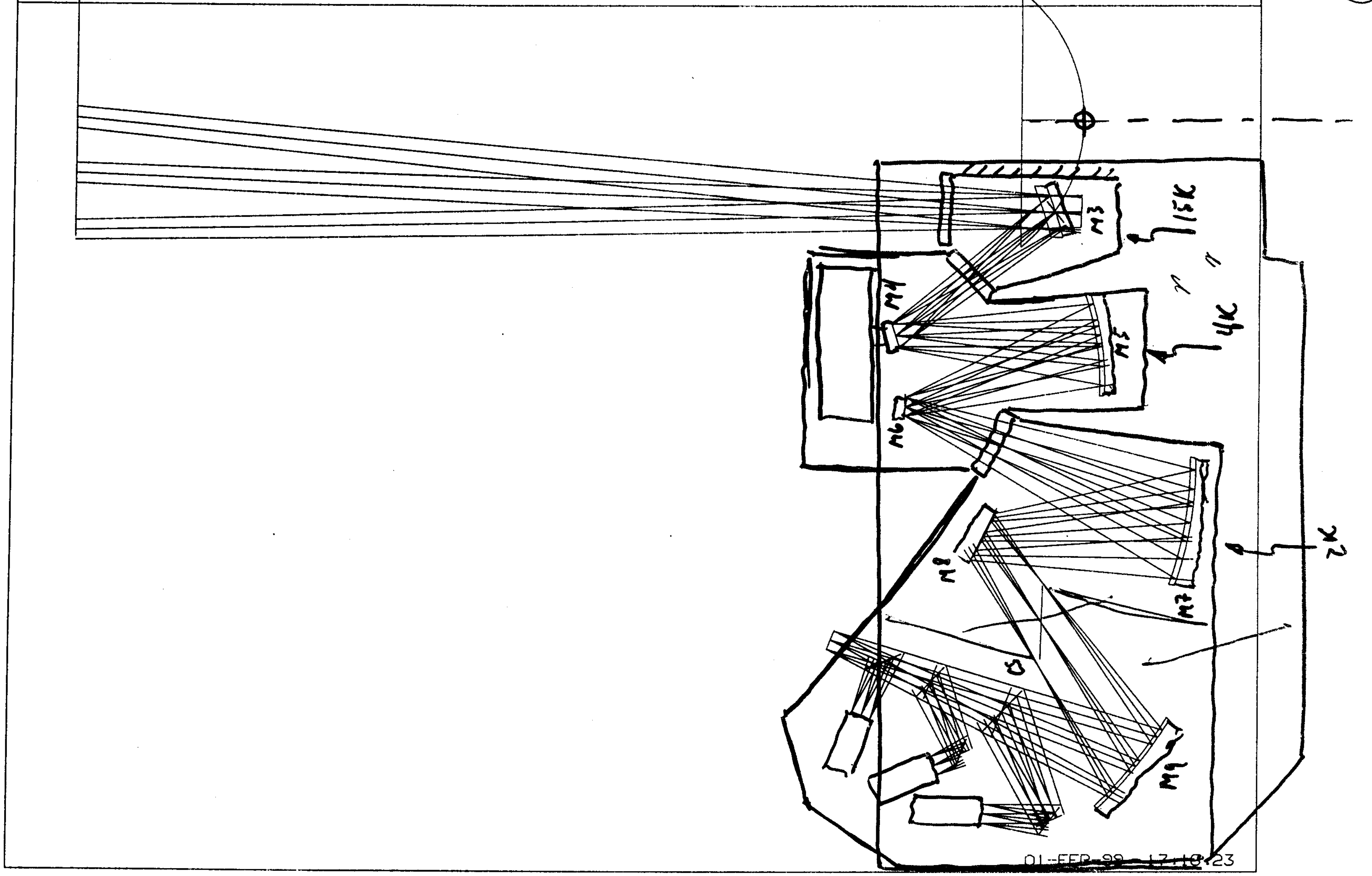
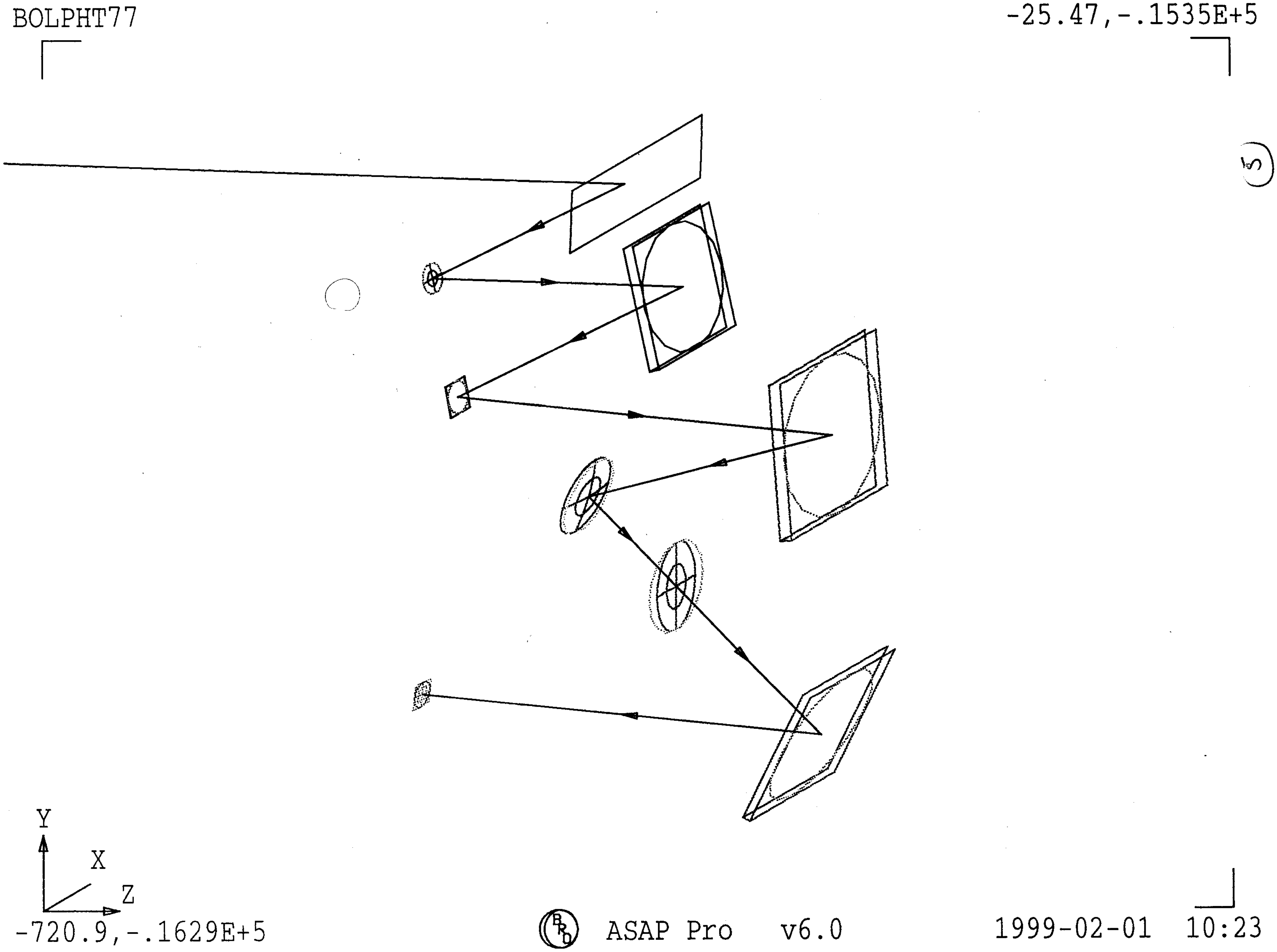
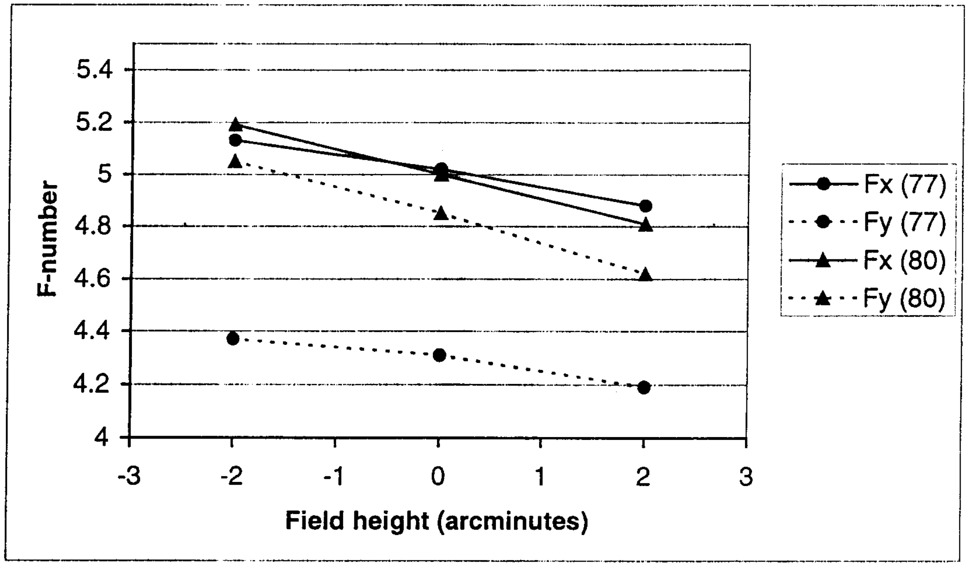



BOLPHT77
-25.47,-.1535E+5
Y
X
Z
-720.9,-.1629E+5
BRO
ASAP Pro v6.0
1999-02-01 10:23

DISTORTION AND ANAMORPHISM

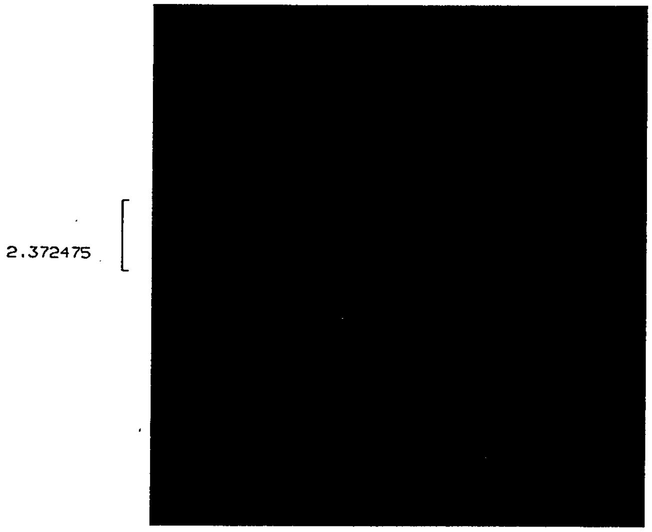
	BOLPHT77	BOLPHT80
Upper edge	Fx = 4.88, Fy = 4.19	Fx = 4.81, Fy = 4.62
Centre	Fx = 5.02, Fy = 4.31	Fx = 5.00, Fy = 4.85
Lower edge	Fx = 5.13, Fy = 4.37	Fx = 5.19, Fy = 5.05

BOLPHT80: max difference is 0.57 (11%)



DIFFRACTION INTENSITY PATTERN

SEMI-FIELD - 0.0167 DEGREES SEMI-APERTURE - 1641.7050 MM



$F_y = 4.85$

$F_x = 5.00$

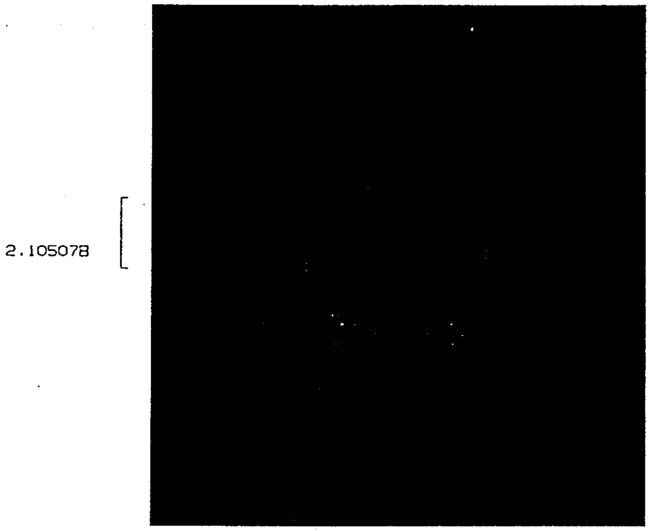
AIRY DISK RADIUS 2.372475 MM
PSPRD 2 0 300 0 0 3.5 R
FRACTIONAL FIELD 0.0000 0.0000

ID FIRST SPIRE PHOT (BOLPHTBO) 150
WAVELENGTH 400.00000

01-FEB-99 14:02:21

DIFFRACTION INTENSITY PATTERN

SEMI-FIELD - 0.0167 DEGREES SEMI-APERTURE - 1641.7050 MM



$F_y = 4.31$

$F_x = 5.02$

AIRY DISK RADIUS 2.105078 MM
PSPRD 2 0 300 0 0 3.5 R
FRACTIONAL FIELD 0.0000 0.0000

ID FIRST SPIRE PHOT (BOLPHT77) 150
WAVELENGTH 400.00000

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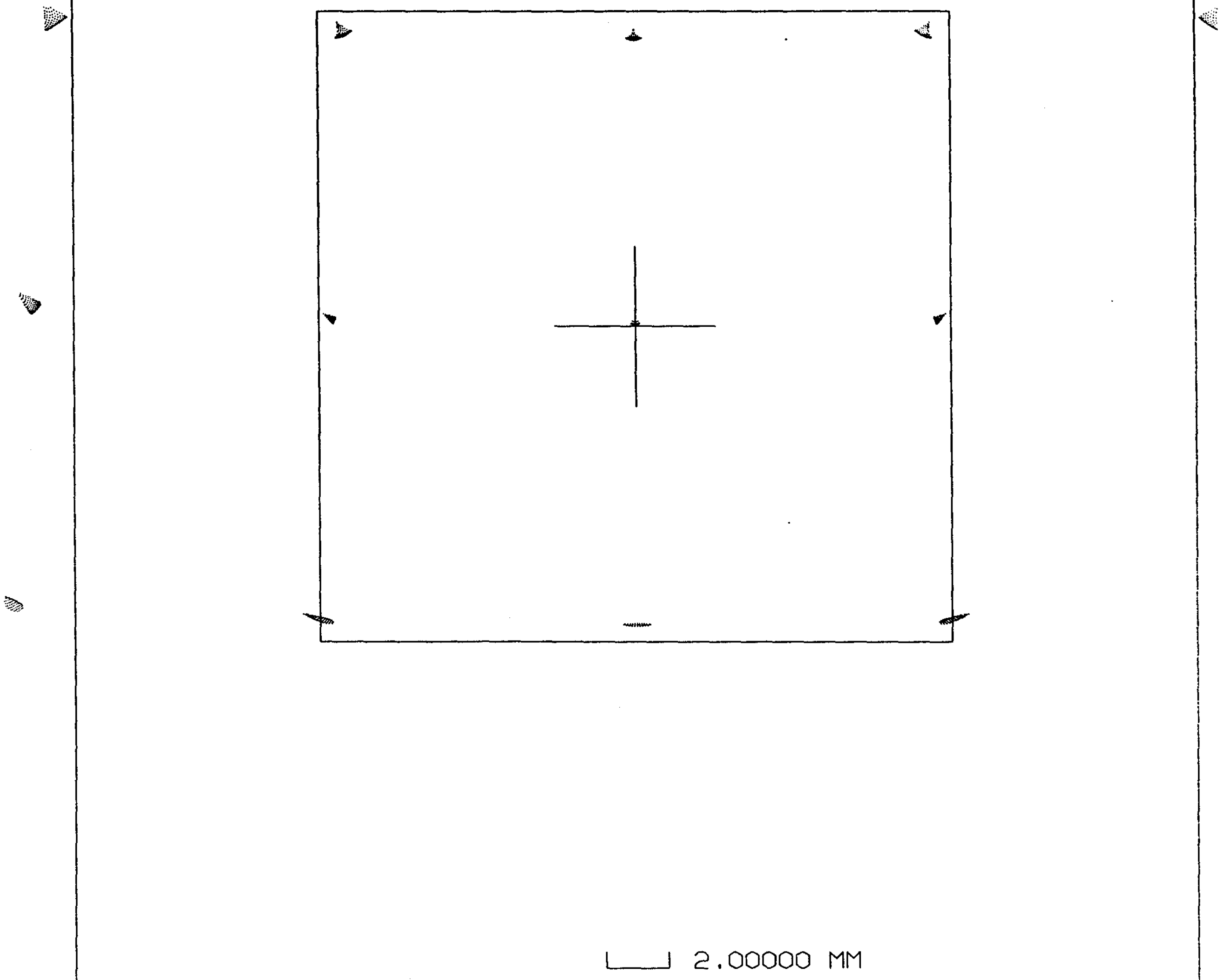
FOOTPRINT ON SURFACE 30

CENTER AT 0.000 0.000

ID FIRST SPIRE PHOT (BOLPHT80) 150

SCALE 5.00



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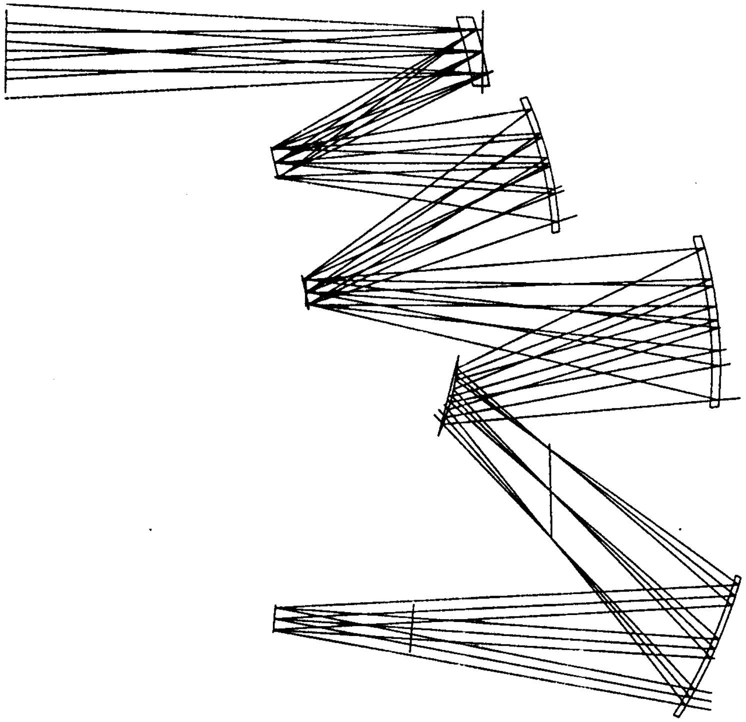
b)

AZIMUTH 0.000 ELEVATION 0.000 SCALE 0.200 ID FIRST SPIRE PHOT (BOLPHT79) 150



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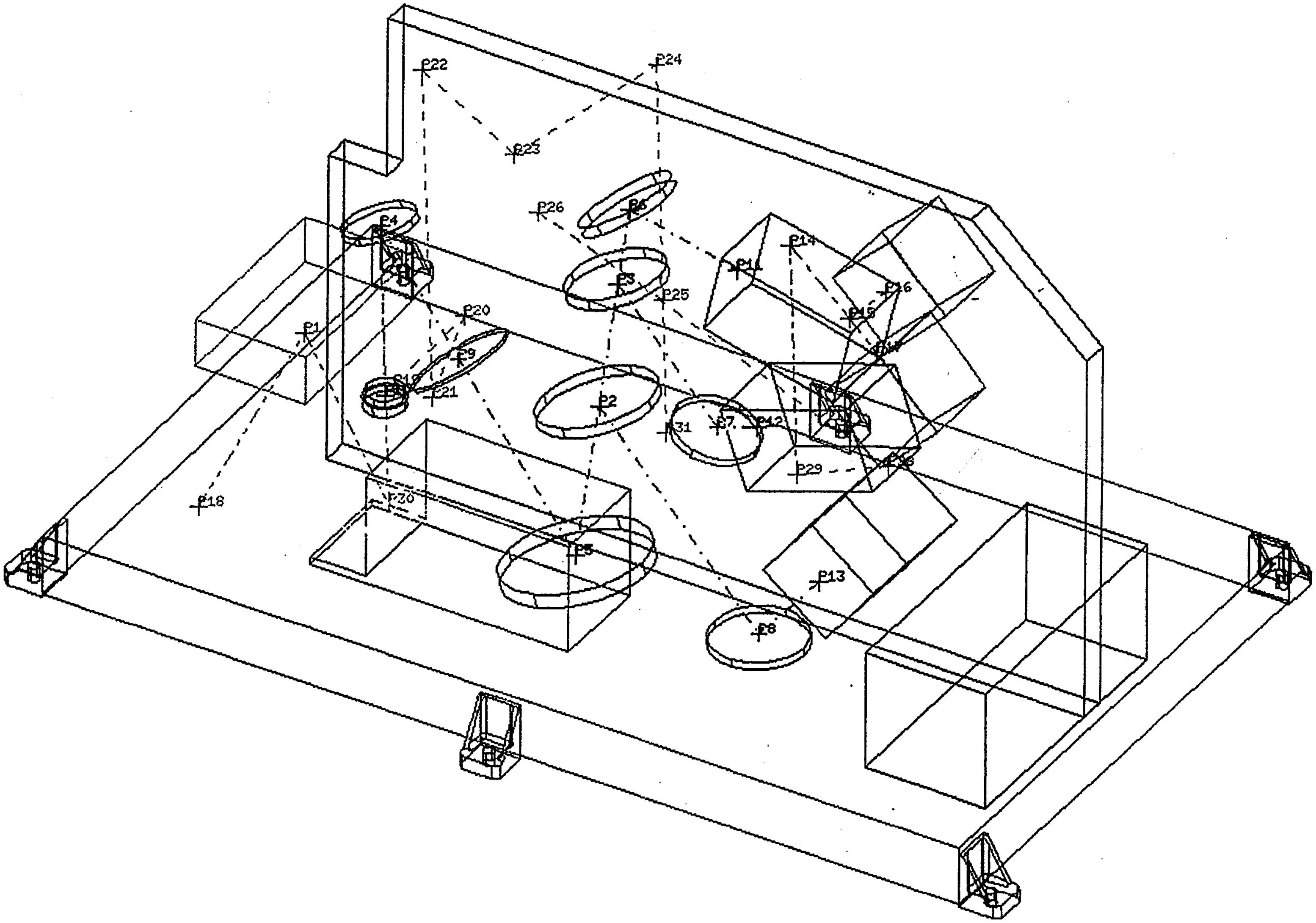

P22
P24
P23
P26
P6
P4
P14
P11
P16
P15
P3
P25
P1
P20
P9
P21
P2
P31
P7
P12
P29
P18
P30
P5
P13
P8

DESIGN REQUIREMENTS

- First natural frequency of >100Hz
- 15K to 4K Heat Leak < 2mWatts
- 4K to 2K Heat Leaks <1mWatt
- Low mass

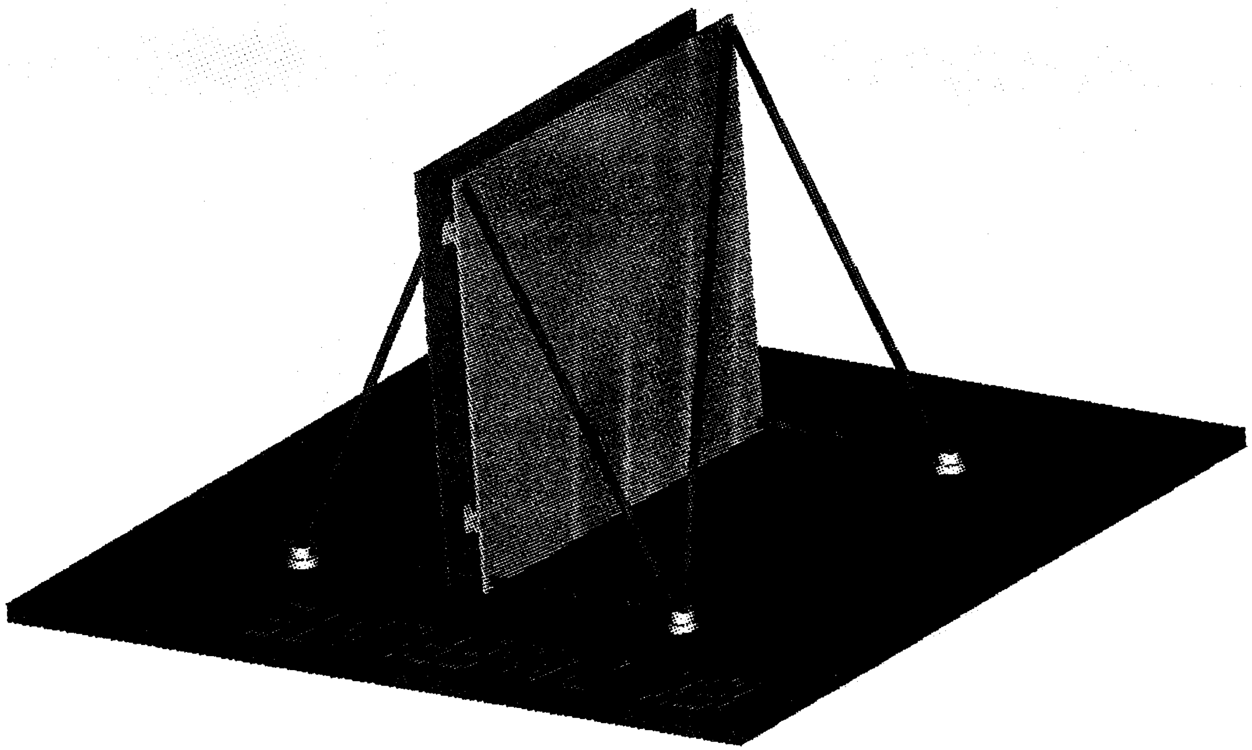
4K to 2K SUPPORT MATERIALS

- Achieving the 1mWatt budget between the 4K and 2K should be achievable, due to the low delta T and the lower mass compared to the 4K support system.
- Initial calculations have shown that a stainless steel blade mounting system would be applicable in this case.

CONFIGURATION 1

- 8 CFRP struts (10mm OD, 1mm wall) from corners of 4K plate to 15K stage.
- 2 diagonal CFRP struts to provide support in 3rd axis.
- Struts pass through clearance holes in 2K plate.
- 2K plate mounted off 4K plate on stainless steel blades.
- Most simple configuration.
- Low heat leaks onto 4K due to long length of struts.

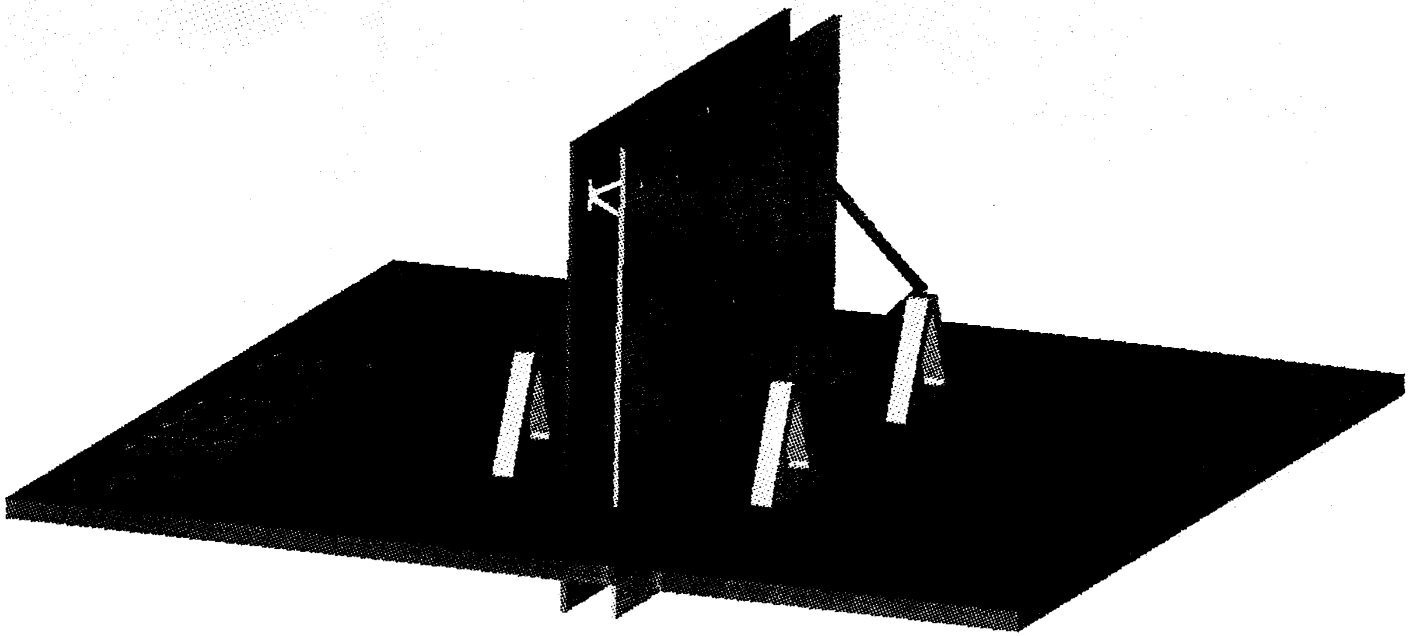
CONFIGURATION 1:



CONFIGURATION 2

- 4K plate lowered through 15K plate by 100mm.
- 8 CFRP struts (10mm OD, 1mm wall) from corners of 4K plate to 15K stage.
- 2 diagonal CFRP struts to provide support in 3rd axis.
- Struts pass through clearance holes in 2K plate.
- 2K plate mounted off 4K plate on stainless steel blades.
- This configuration has a lower C of G and a stiffer support structure than Configuration 1.
- Higher heat leaks due to shorter struts.

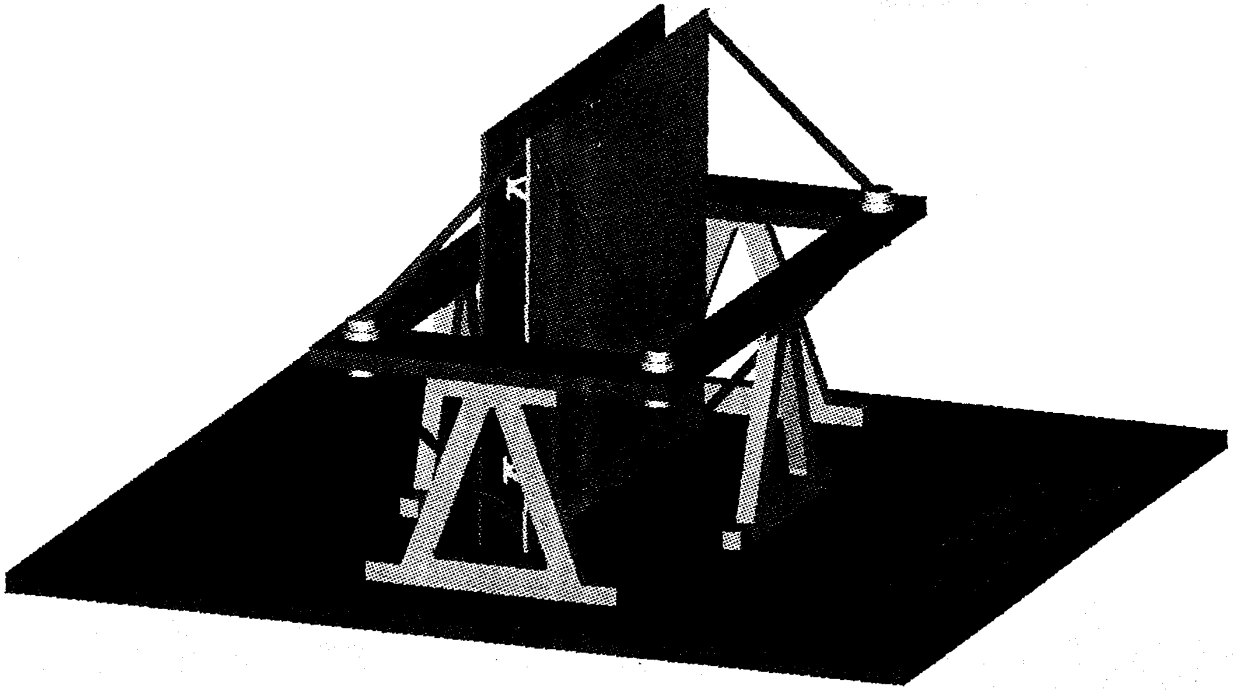
CONFIGURATION 2:



CONFIGURATION 3

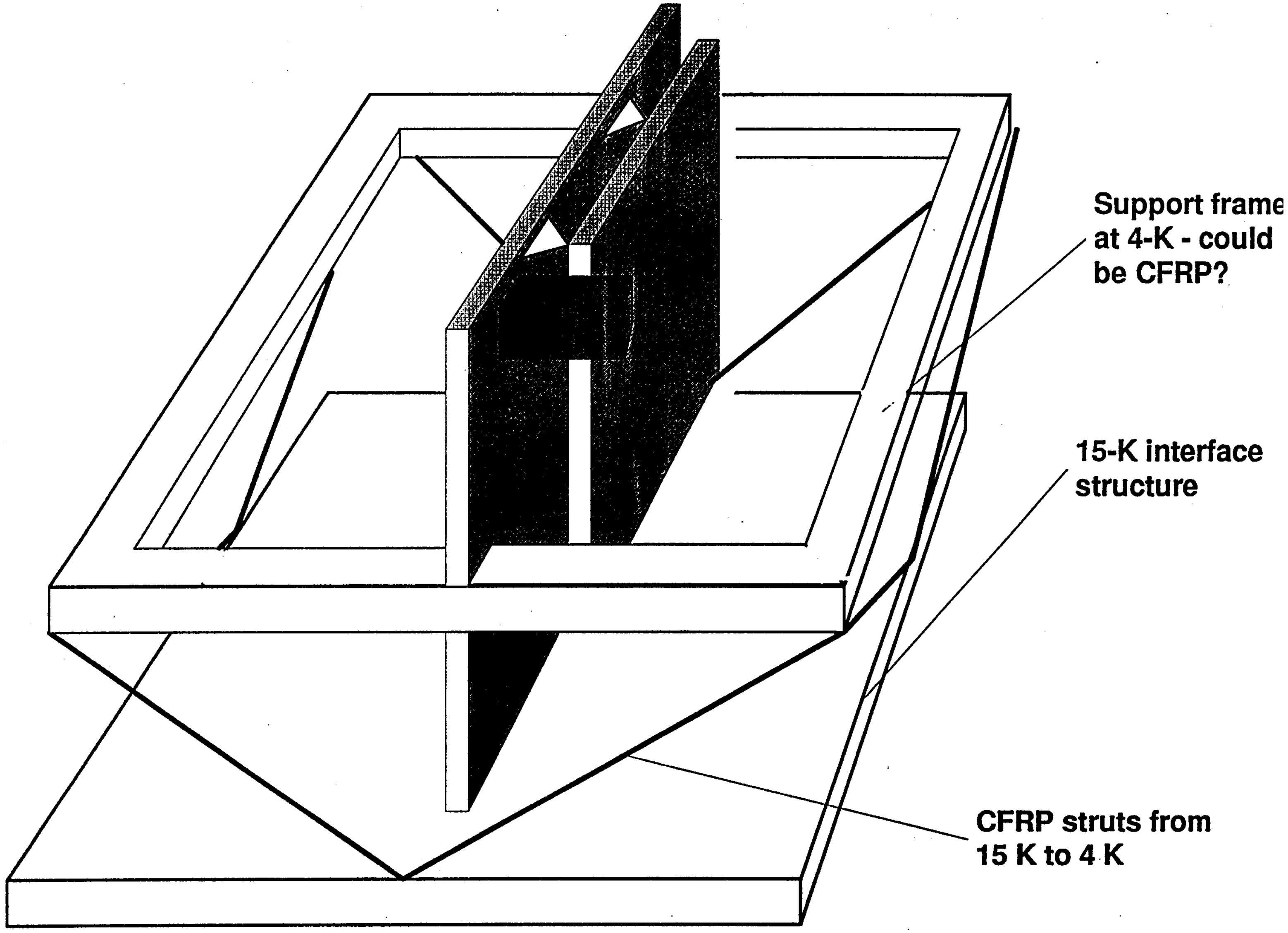
- Support frame used to mount the 15K plate from the baseplate, at the mid-height of the 4K plate.
- 8 CFRP struts (10mm OD, 1mm wall) from corners of 4K plate to 15K stage.
- 2K plate mounted off 4K plate on stainless steel blades.
- Struts do not interfere with optics in this configuration.
- High mass due to support frame.

CONFIGURATION 3:

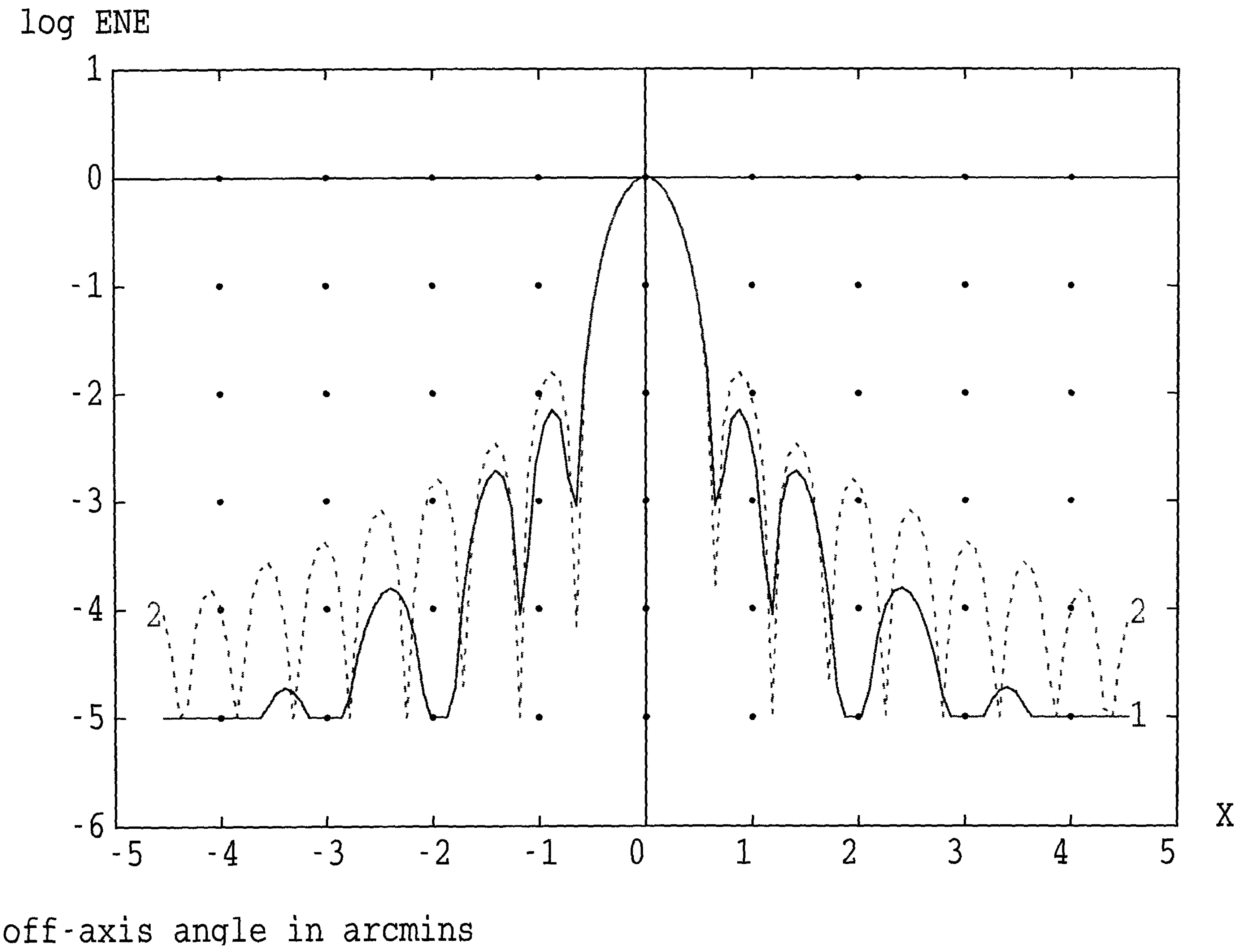


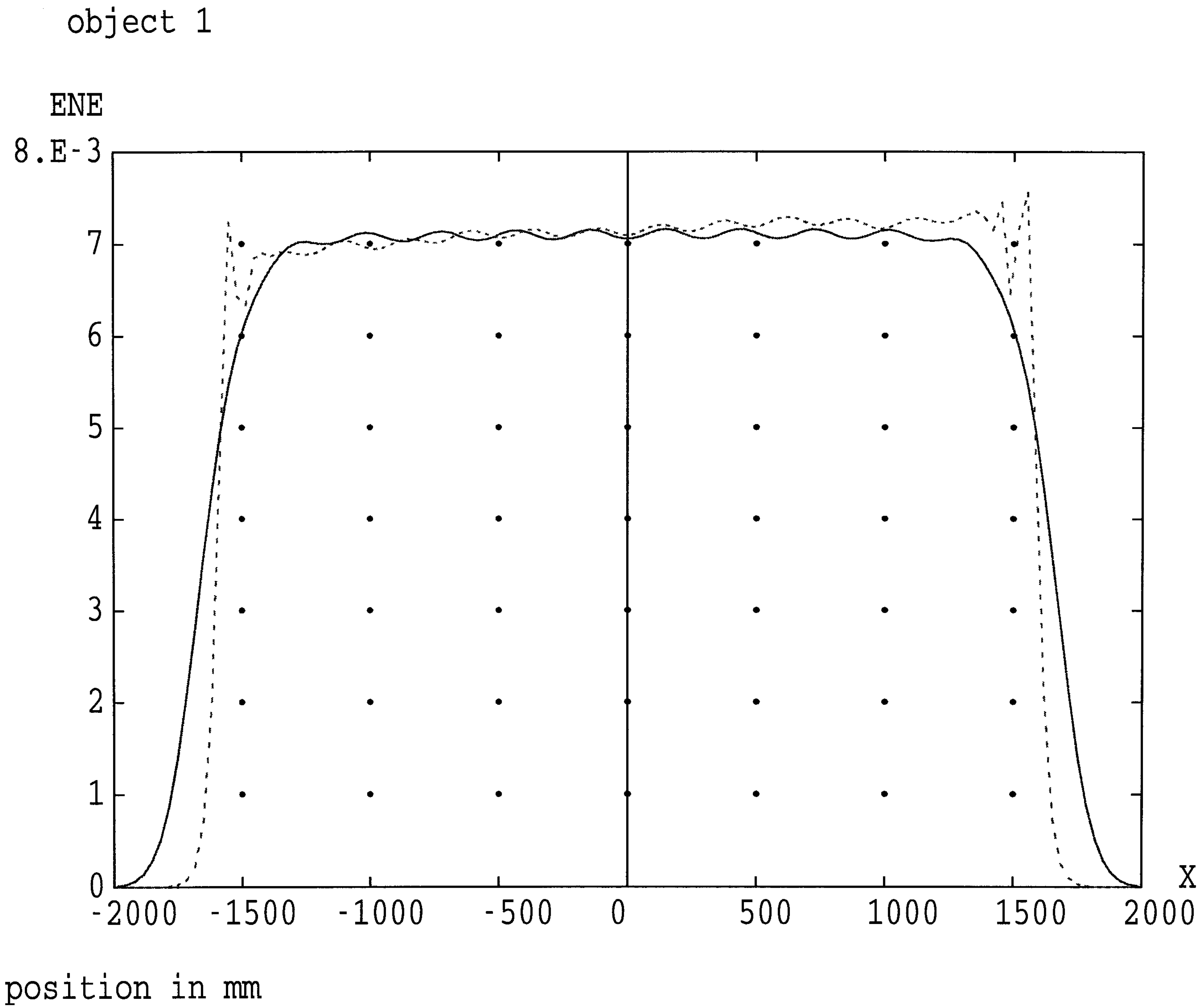
PERFORMANCE COMPARISON

	Configuration 1	Configuration 2	Configuration 3
First Natural Frequency	100Hz	120Hz	TBD
Heat Leaks 15K to 4K	0.4mW	0.8mW	0.4mW

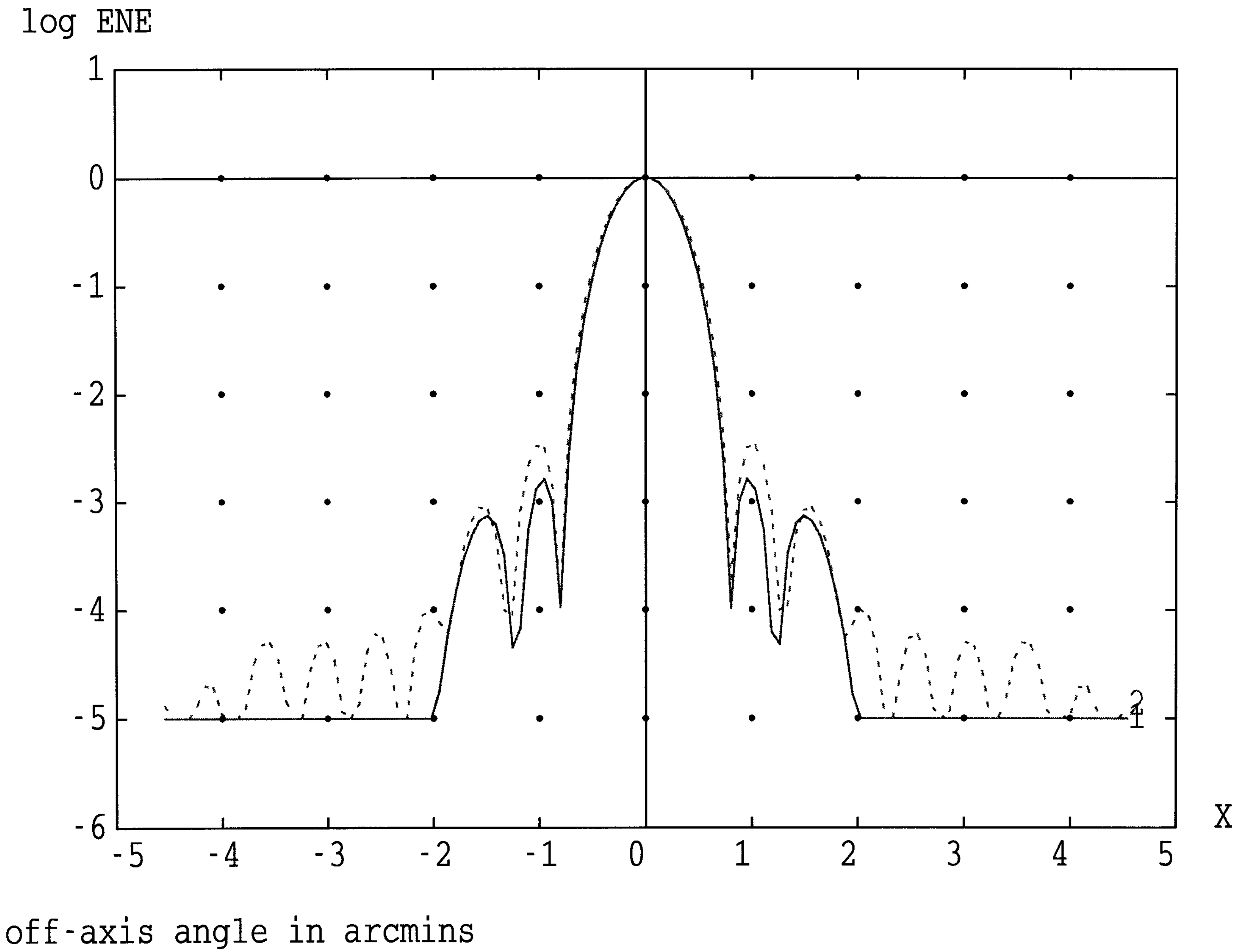

Support frame at 4-K - could be CFRP?
15-K interface structure
CFRP struts from 15 K to 4 K

OBJ 12 SKY beam pattern, far-field

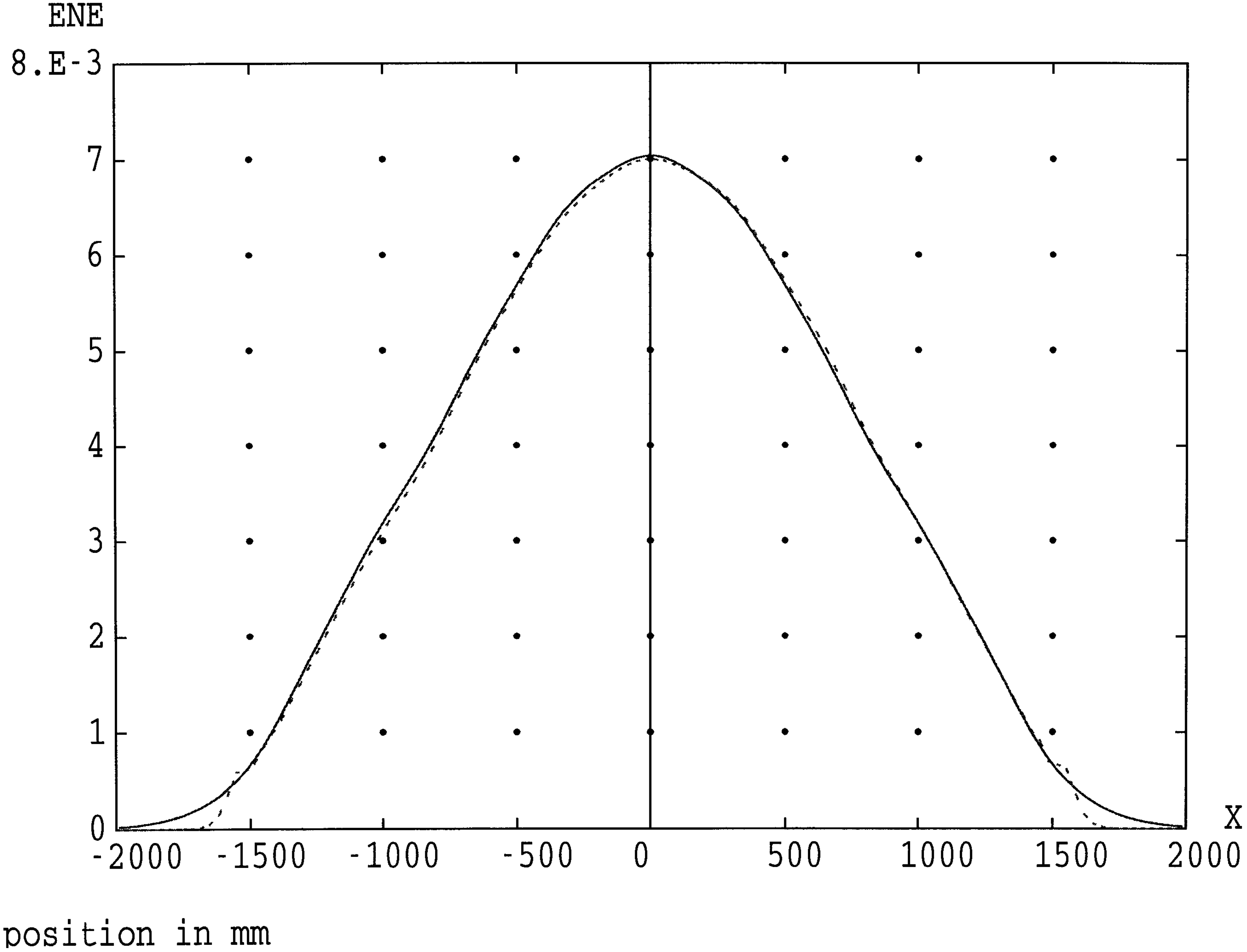



object 1
ENE
8.E-3
7
6
5
4
3
2
1
0
-2000
-1500
-1000
-500
0
500
1000
1500
2000
X
position in mm

OBJ 12 SKY beam pattern, far-field



object 1


ENE
8.E-3
7
6
5
4
3
2
1
0
-2000
-1500
-1000
-500
0
500
1000
1500
2000
X
position in mm

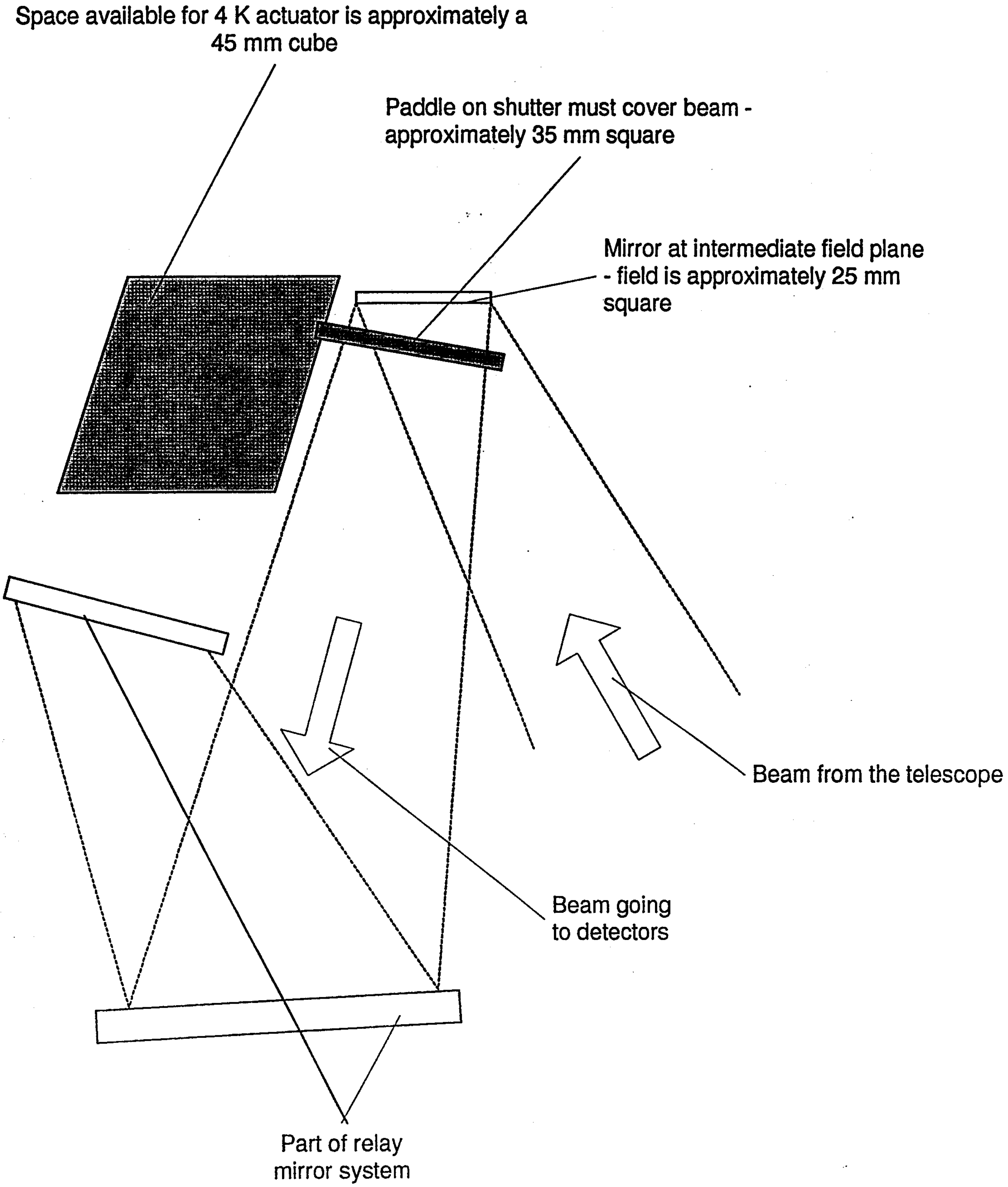
Portion of M2 Surround	**Beam fraction B_s**	**Surround emissivity**	**Temp.**	**Background level η**
Non-spider, (space viewing)	0.13	1	Cold space	**?**
Spider	0.13x 1/16	1	Telescope	**0.4**

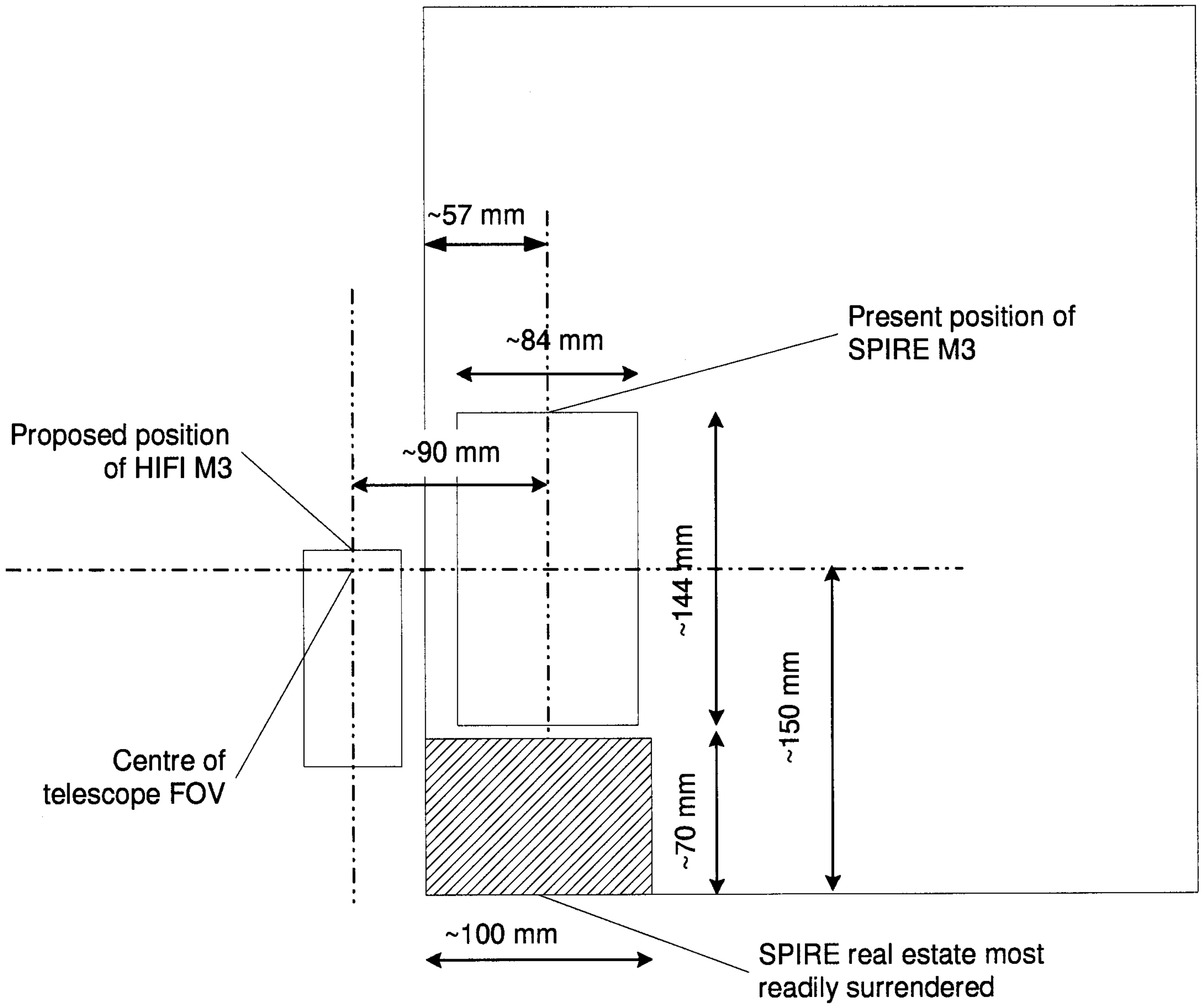
top-hat

Portion of M2 Surround	**Beam fraction B_s**	**Surround emissivity**	**Temp.**	**Background level η**
Non-spider, (space viewing)	0.02	1	Cold space	**?**
Spider	0.02x 1/16	1	Telescope	**0.06**

gaussian

Table 1. Stray light level from M2 surround for top-hat & gaussian cases.


Space available for 4 K actuator is approximately a 45 mm cube
Paddle on shutter must cover beam - approximately 35 mm square
Mirror at intermediate field plane - field is approximately 25 mm square
Beam from the telescope
Beam going to detectors
Part of relay mirror system


~57 mm
~84 mm
Present position of SPIRE M3
Proposed position of HIFI M3
~90 mm
~144 mm
~150 mm
Centre of telescope FOV
~70 mm
~100 mm
SPIRE real estate most readily surrendered

Photometer Optics Workplan:

2/3 Feb – Optics/FTS meeting

Decide on essentials of photometer optical design.

Outstanding issues preventing completion of detailed design:

- **FOV (can we decide this now?);** 4x8
- **Detector Type;**
- **Telescope optical design** MID - 1999.
- **.....**

Issues that can be addressed "generically":

- **Translation into CAD system;**
- **Do we care about position in focal plane;** NO.
- **Analysis of spot size/distortion;** 5% IN THROUGH
- **Error budget;** — 10% LOSS IN SR.
- **Alignment tolerance for each mirror;**
- **Diffraction analysis;** NOT INCLUD FILTERS + MIRROR TRANSMISS
- **Straylight analysis** — BAFFLES.
- **......**FILTERING REQUIREMENTS + PERFORMANCE

Next dates:

15 Feb Focal Plane sharing meeting at ESTEC

4/5 March System Team Meeting

~8 March "Opto-mechanical conceptual design progress review" (MSSL)

OPTICAL COMPONENTS SIZED + POSITIONED
DETECTORS IN PLACE
COOLER IN PLACE
CHOPPER
SHUTTER, IF NEEDED.
STRUCTURAL SUPPORT CONCEPT
CONCEPT FOR COVERS. — THERMAL
FREQ
VIB. → DESIGN CASE.
MASS ESTIMATE.

15 March ESA Technical Meeting

Mid/Late-April "Opto-mechanical conceptual design progress review" 8

July ESA Technical Meeting to "close" s/c interfaces

esa

FIRST/Planck Project

Telefax

Fax No : (31) 71 565 5244
Tel. No : (31) 71 565 5962

Ref. : PT-05908 **Date** : 5 October, 1998

From : T. Passvogel (SCI-PT) **Page** : 1 of 2

To		**Fax No:**
:	M. Griffin (QMWC/London)	44 181 980 0986
	A. Poglitsch (MPE/Garching)	49 89 3299 3292
	Th. de Graauw (SRON/Groningen)	050 363 4033
	K. King (RAL/Oxfordshire)	44 1235 44 6667
	B. Swinyard (RAL/Oxfordshire)	44 1235 44 6667
	O. Bauer (MPE/Garching)	49 89 3299 3569
	H. Aarts (SRON/Utrecht)	030 254 0860
	D. Beintema (SRON/Groningen)	050 363 4033

To : F. Felici, M. Anderegg, H. Schaap, B. Guillaume, B. Collaudin, G. Pilbratt

Subject : FIRST/Planck - FIRST FPU/Optical Bench Optimisation
Ref. : MoM of the FIRST Telescope Meeting (PT-MM-05886), held at 30.09.98 at ESTEC

Please find below as input to your considerations on the optimisation of the optical bench layout the close-out of the AI #10 of the above ref. meeting:

> "ESA to provide to the instruments the geometry of the Instrument Shield"

The definition from industry is a set of coordinates that describe the shield. The coordinates are in the spacecraft system with the origin in the centre of the optical bench.
Please use the values as an approximation of the envelope with a requirement set by industry keep a minimum distance of 15 mm between the FPU and the shield.

The maximum size of the shield can be assumed symmetric around the x-axis (the coordinates below provide a cut along the z-axis).

The final value indicates the diameter of the Baffle opening of 270 mm (2 * 135 mm).

x	y	z
0	0	815
271	0	815
315	0	807
350	0	787
379	0	758
431	0	662
461	0	563
497	0	337
504	0	135

Best regards

T. Passvogel

Wednesday 3 Feb

Start 9:00 (or 9:30 if you prefer?) Rm 6.01

9-10 PARA NOT HERE
9:30 IN THE LAB.
PAH DEMO.

Choice of FTS and FTS detailed requirements

i) Report from PARA on the breadboard FTS (PARA)
Peter A's intensity beam splitting FTS is up and running - does it work?
Perhaps we could start in the lab?

ii) Optical design for the FTS (KD)
Hopefully Kjetil will have a layout we can discuss (?)

iii) Which one should we go for (discussion - refereed by BMS)
We have to make the decision on which one to actively study from now on........

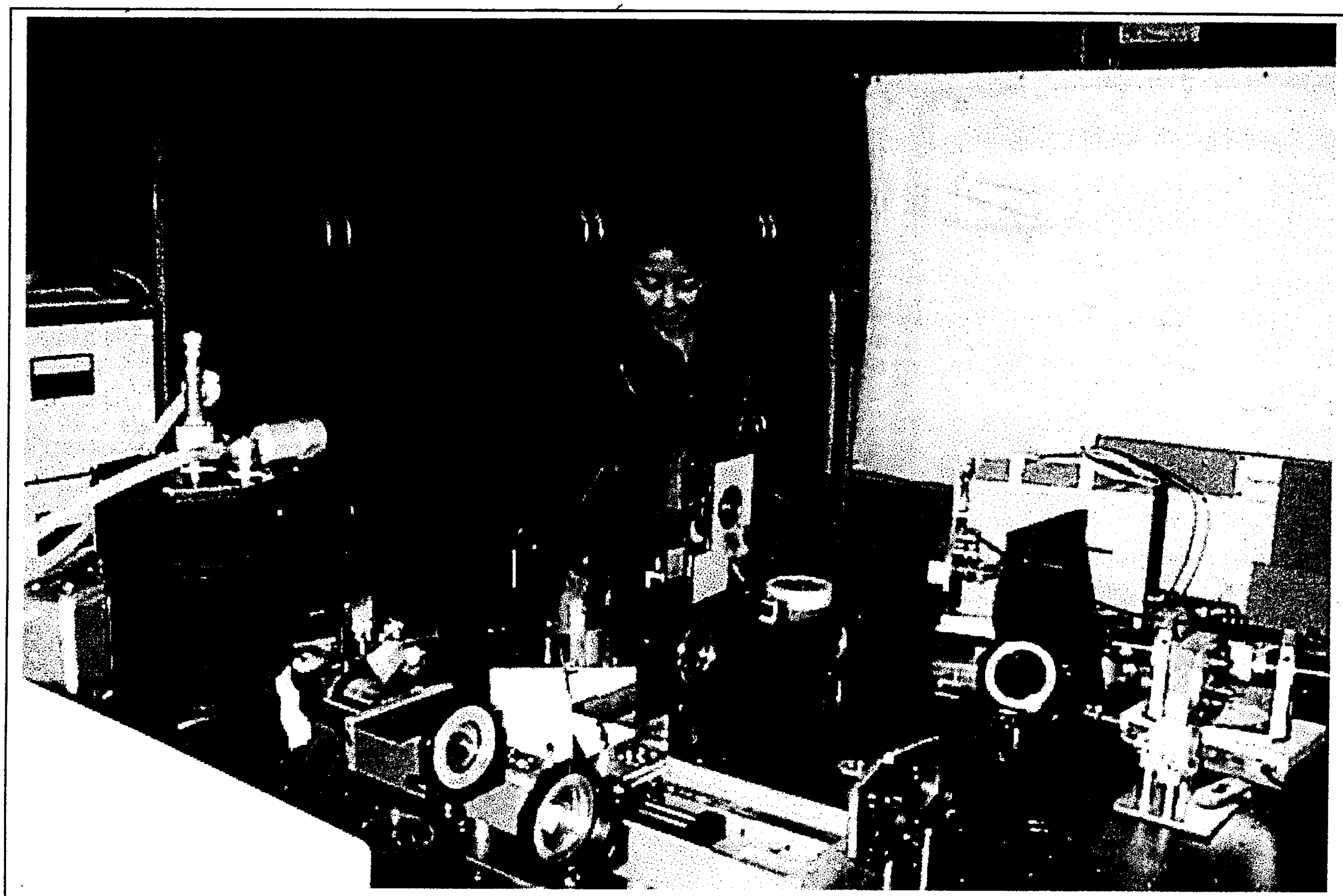
iv) FTS Mechanism - requirements; performance of candidate mech; mechanical design
- errr hopefully someone has something here Guy Michel; Kjetil; Dominique?

v) Scientific Requirements on the FTS (JPB, BMS+....)
These are very unsatisfactorily covered in the Science Requirements doc. Hopefully we can pin them down at this meeting and close the multitude of actions associated with them!

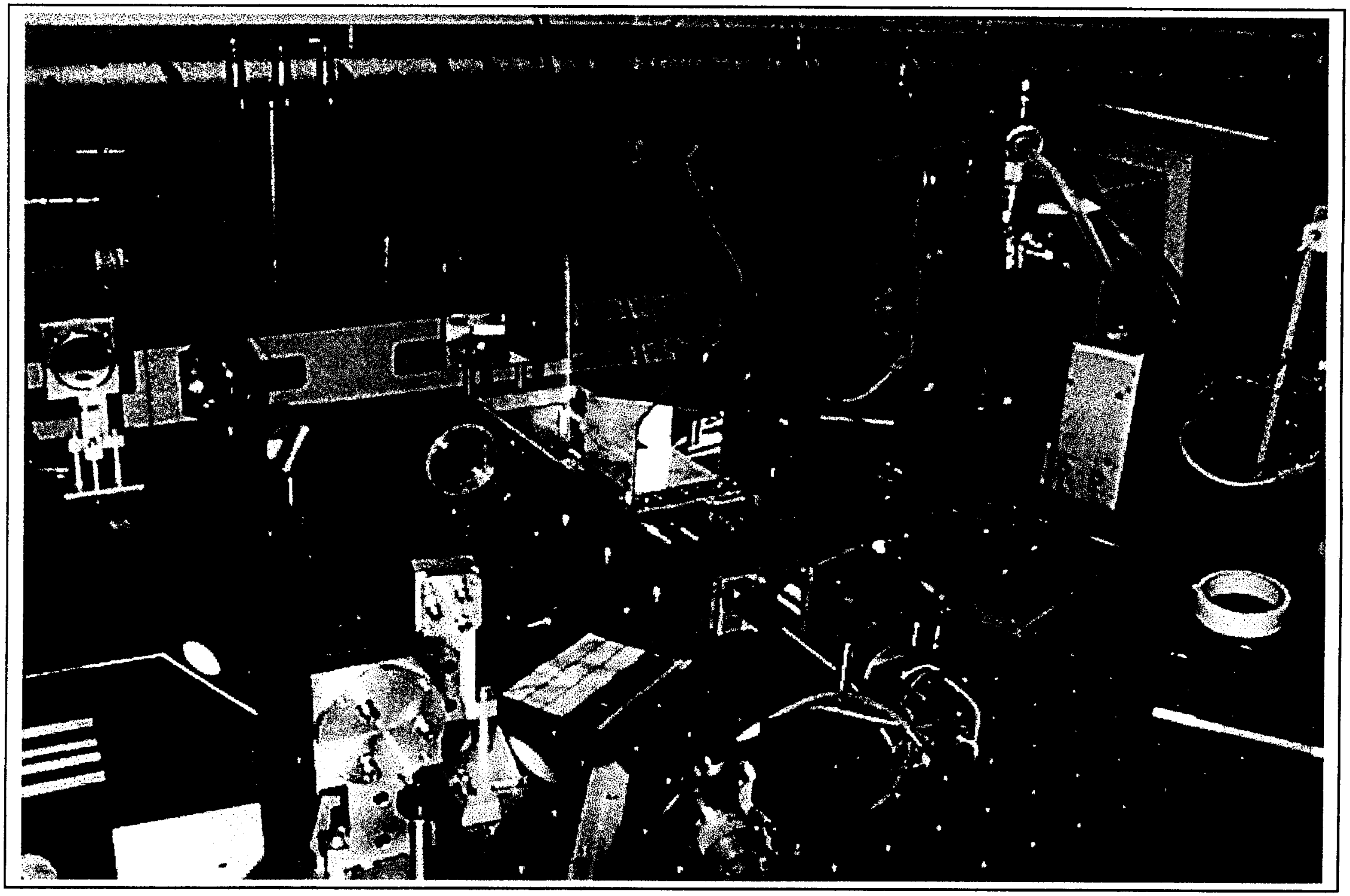
vi) Processing requirements for the FTS (PAH + ?):
Let's see if we can't >agree< some requirements to be written up and used by the electronics folk - please let me know if you have something to present here.

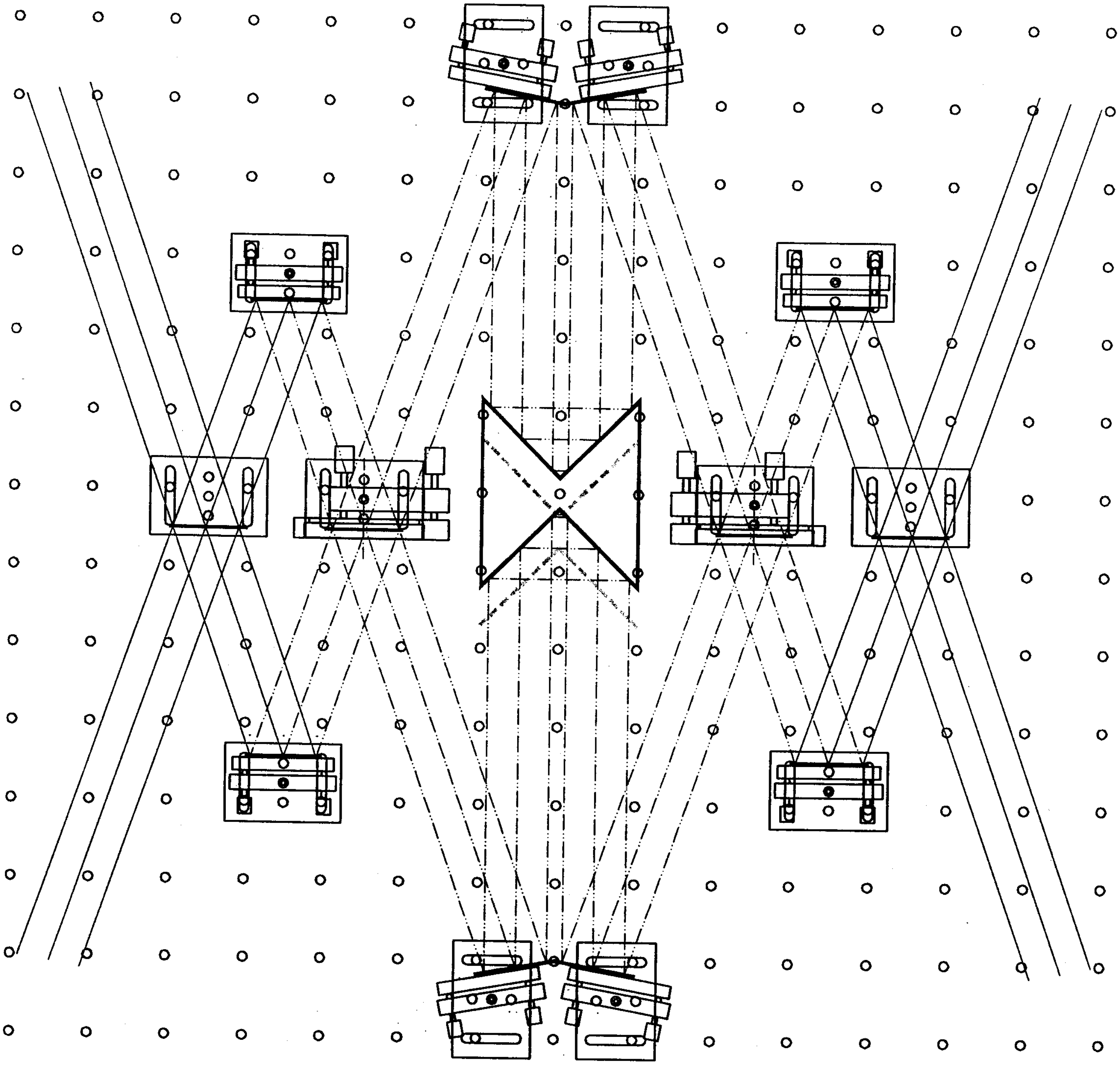
vii) Workplan and goals (BMS) 16:30 Finish
As with the opto-mechanical systems we need to agree a modus operandii for the FTS work - do we need further meetings? Again I will present a skeleton workplan and goals to prompt discussion.

Breadboard Dual-beam FTS

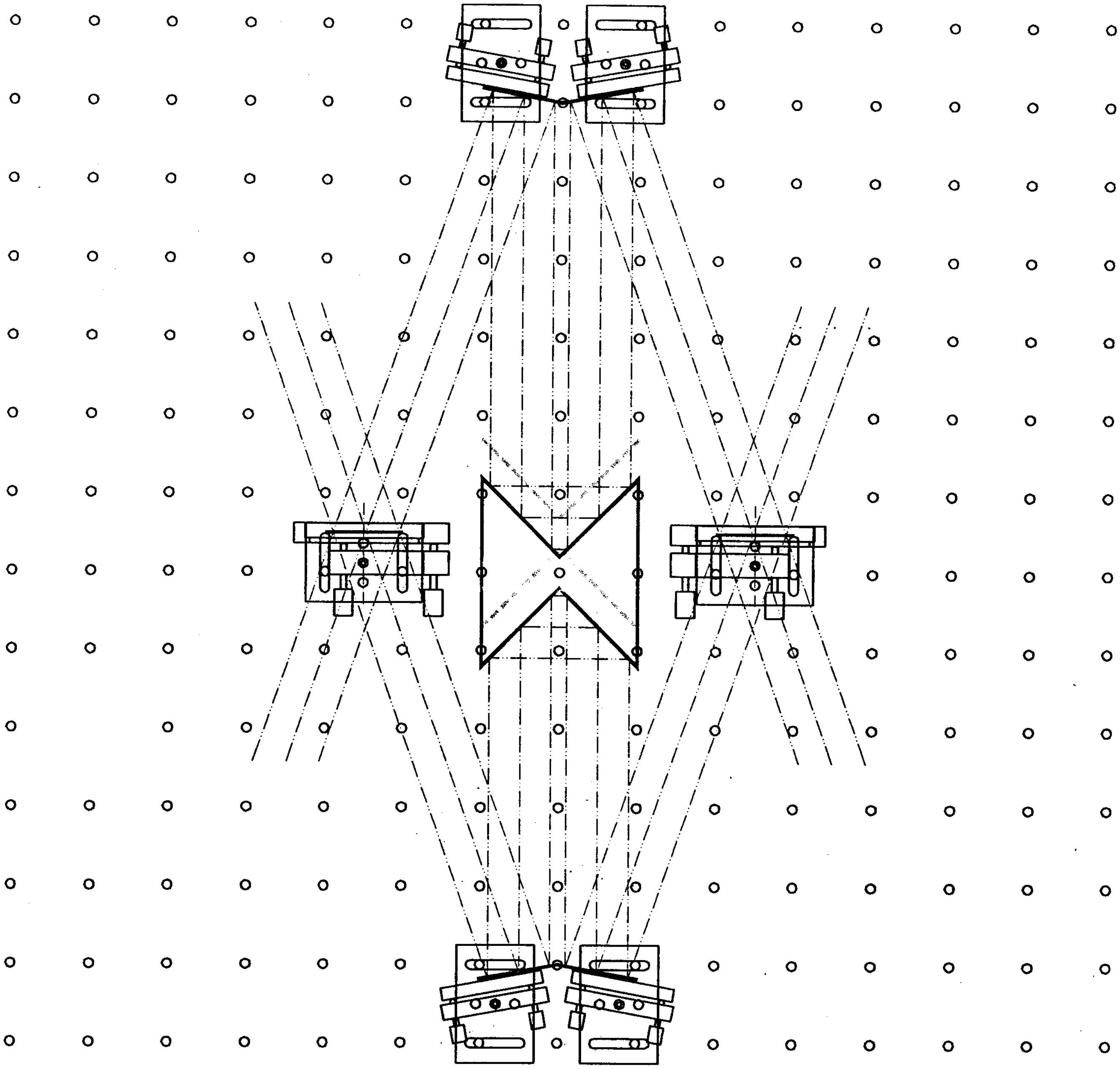


Breadboard Dual-beam FTS

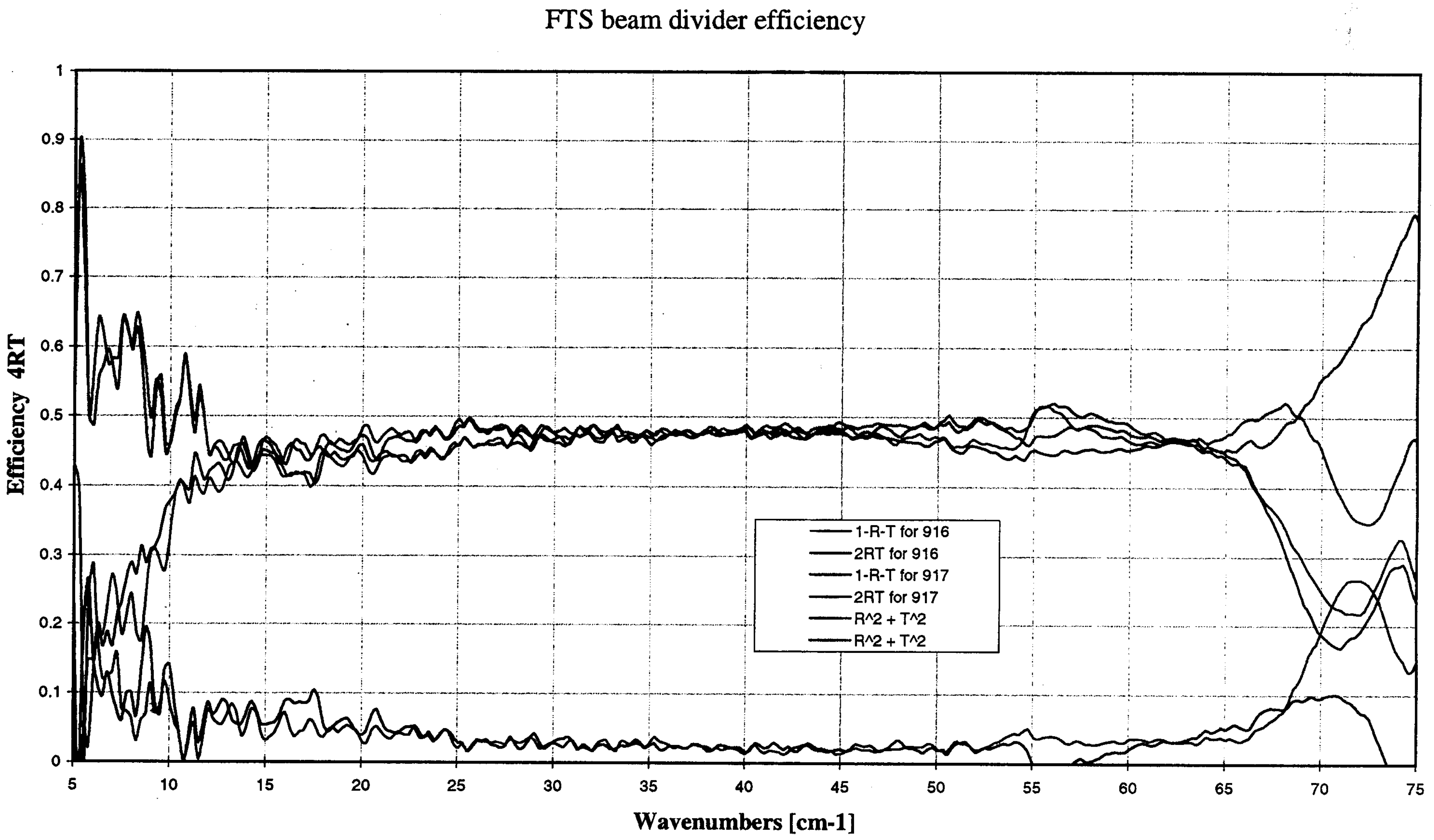




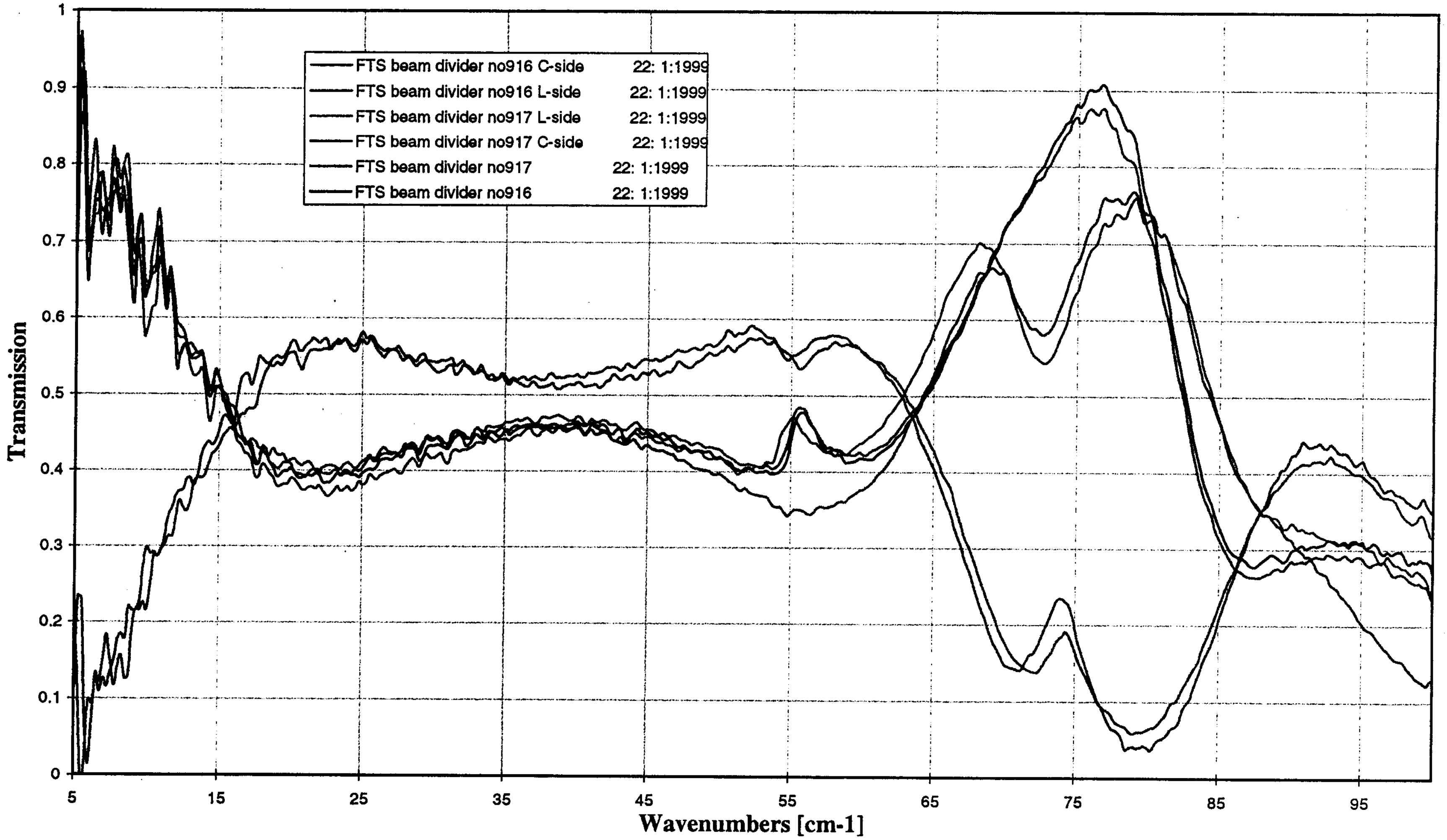
35



(36)

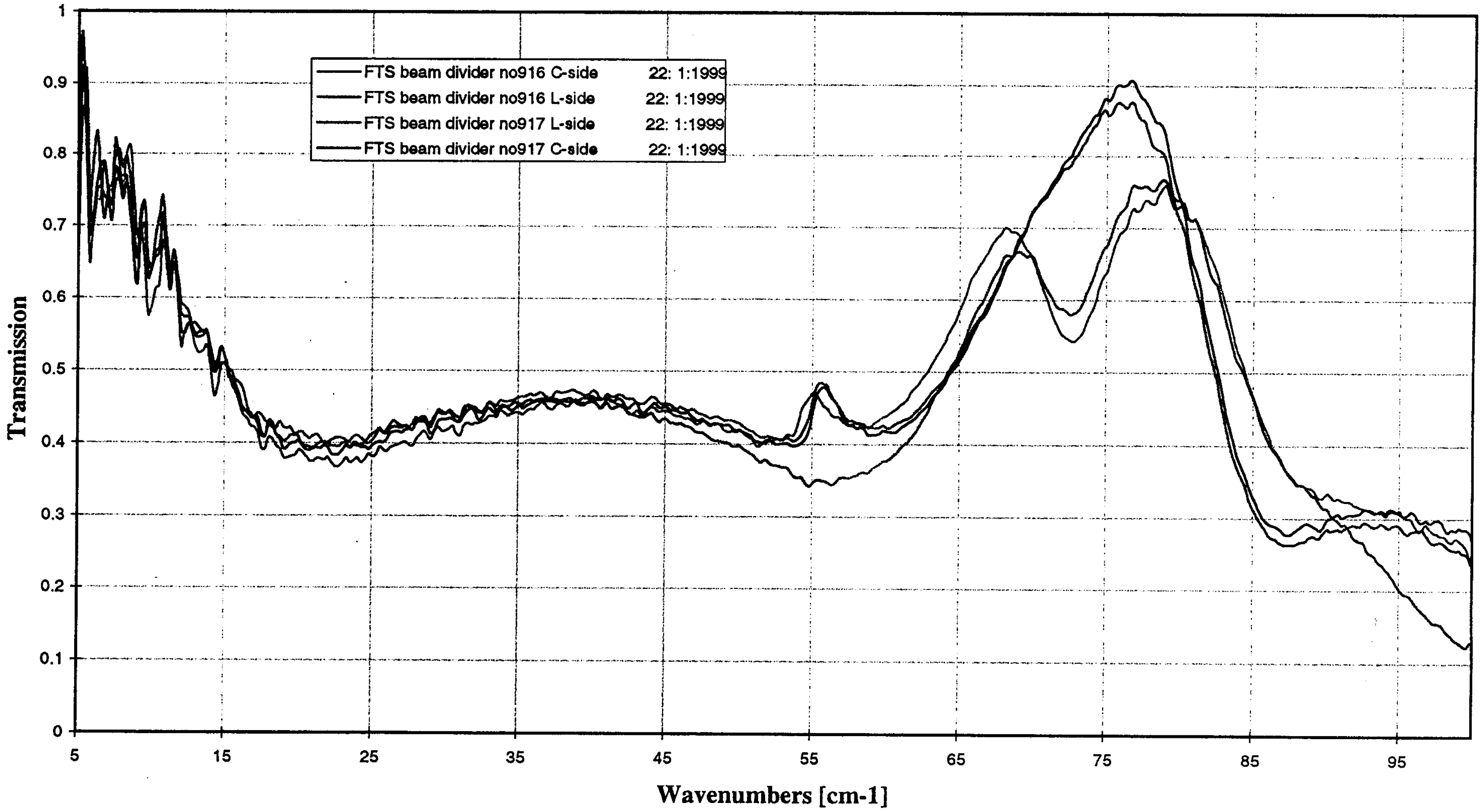


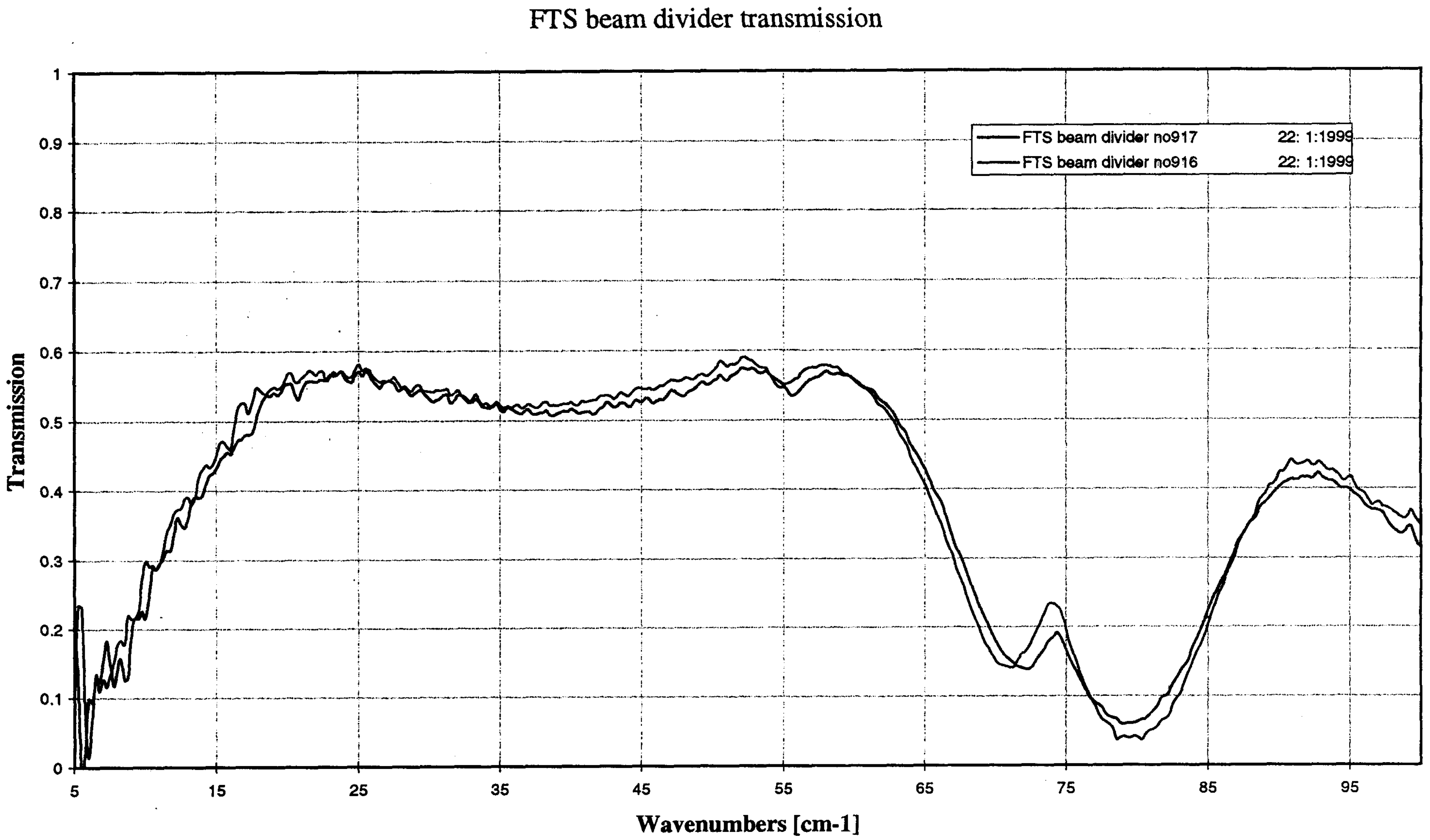
FTS beam divider efficiency

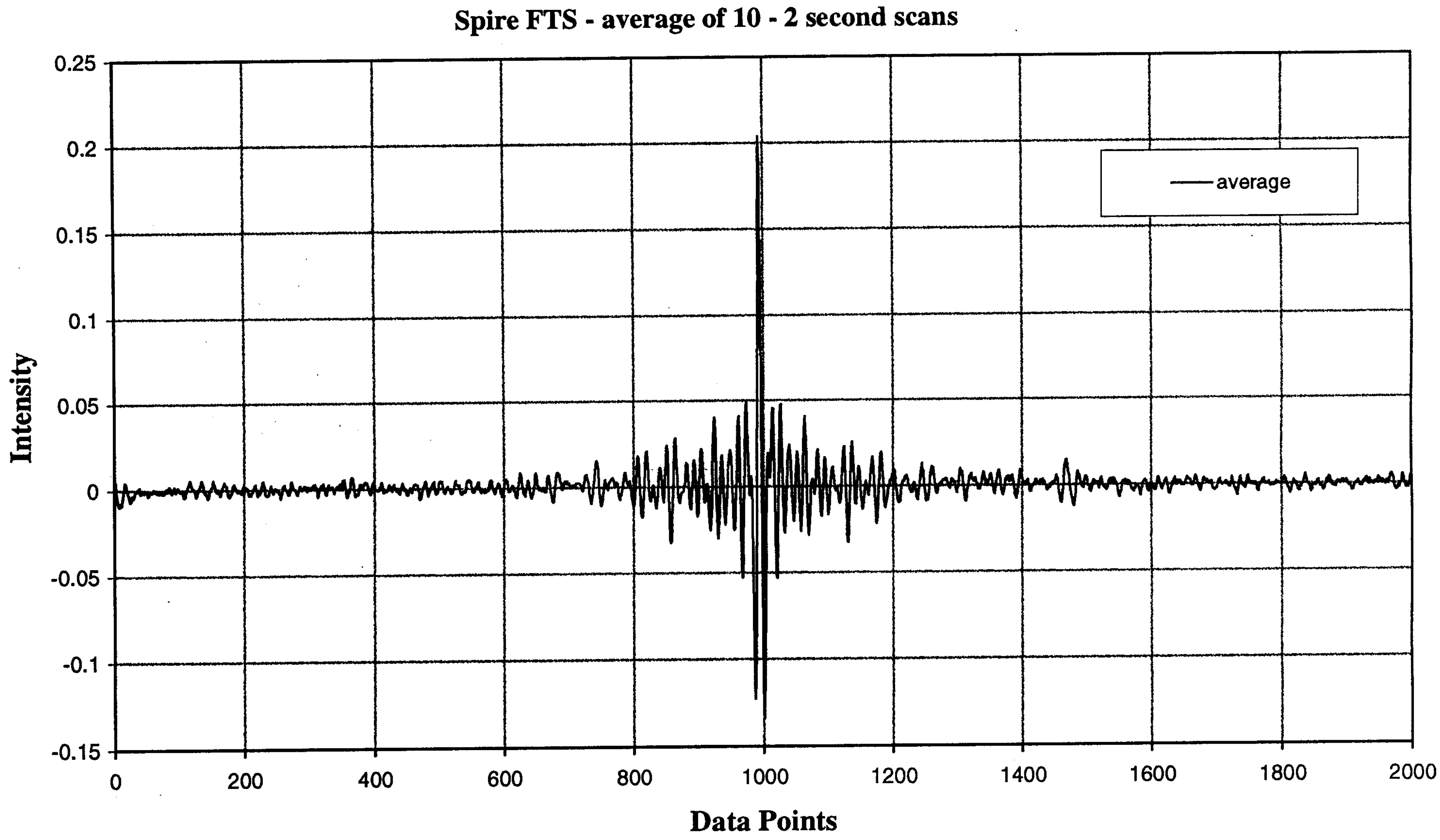


FTS beam divider reflectivities

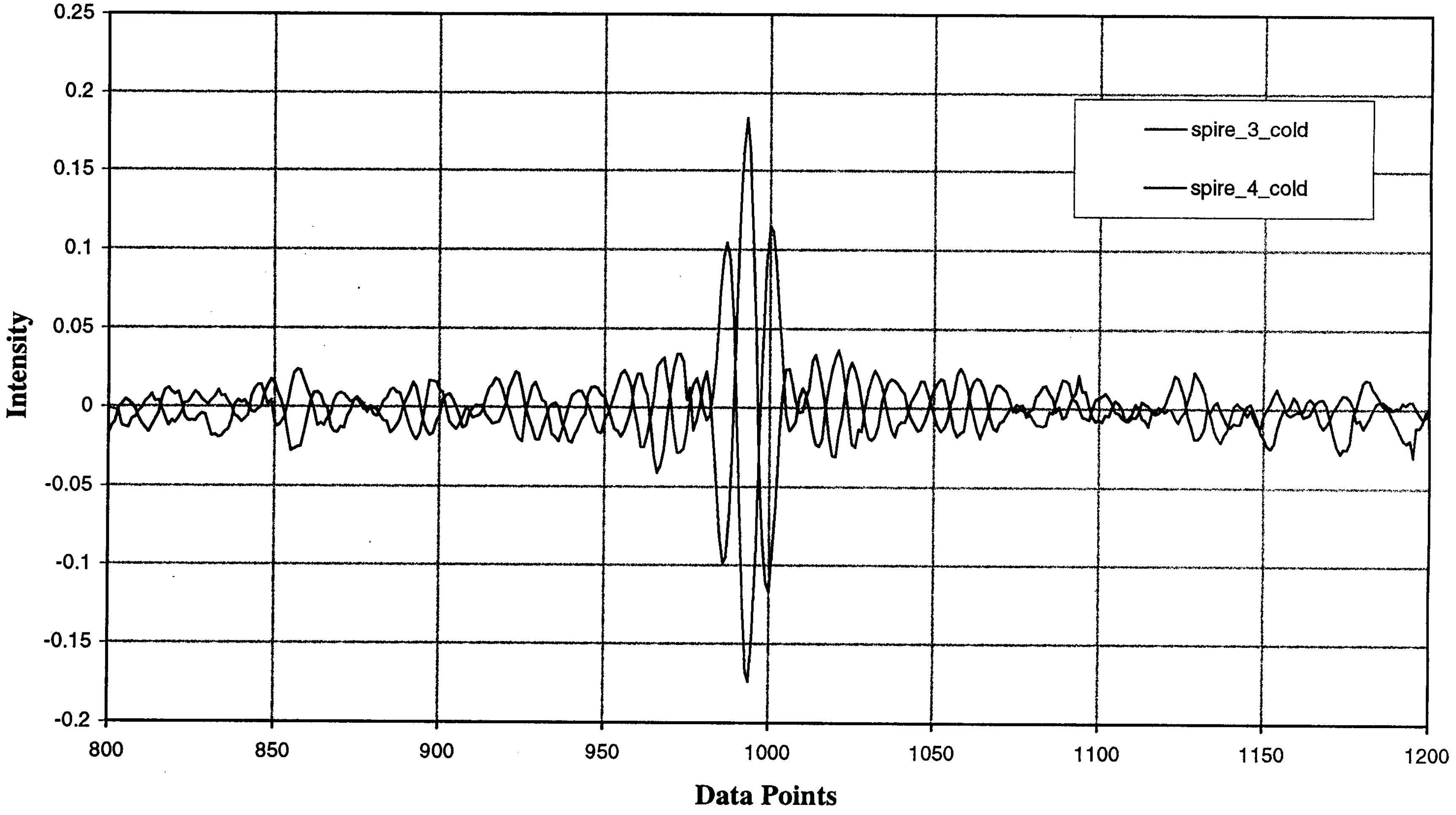
FTS beam divider reflectivities

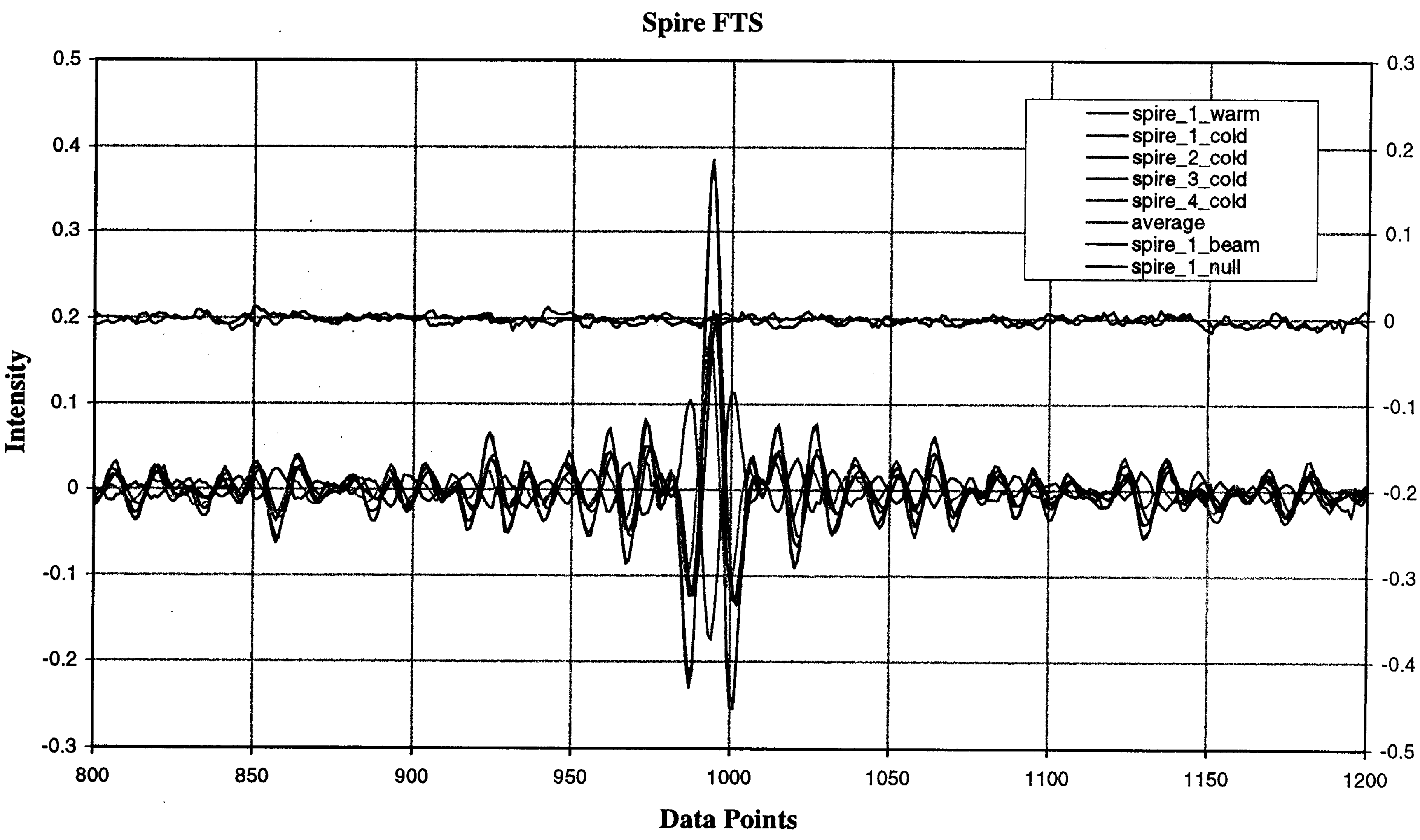


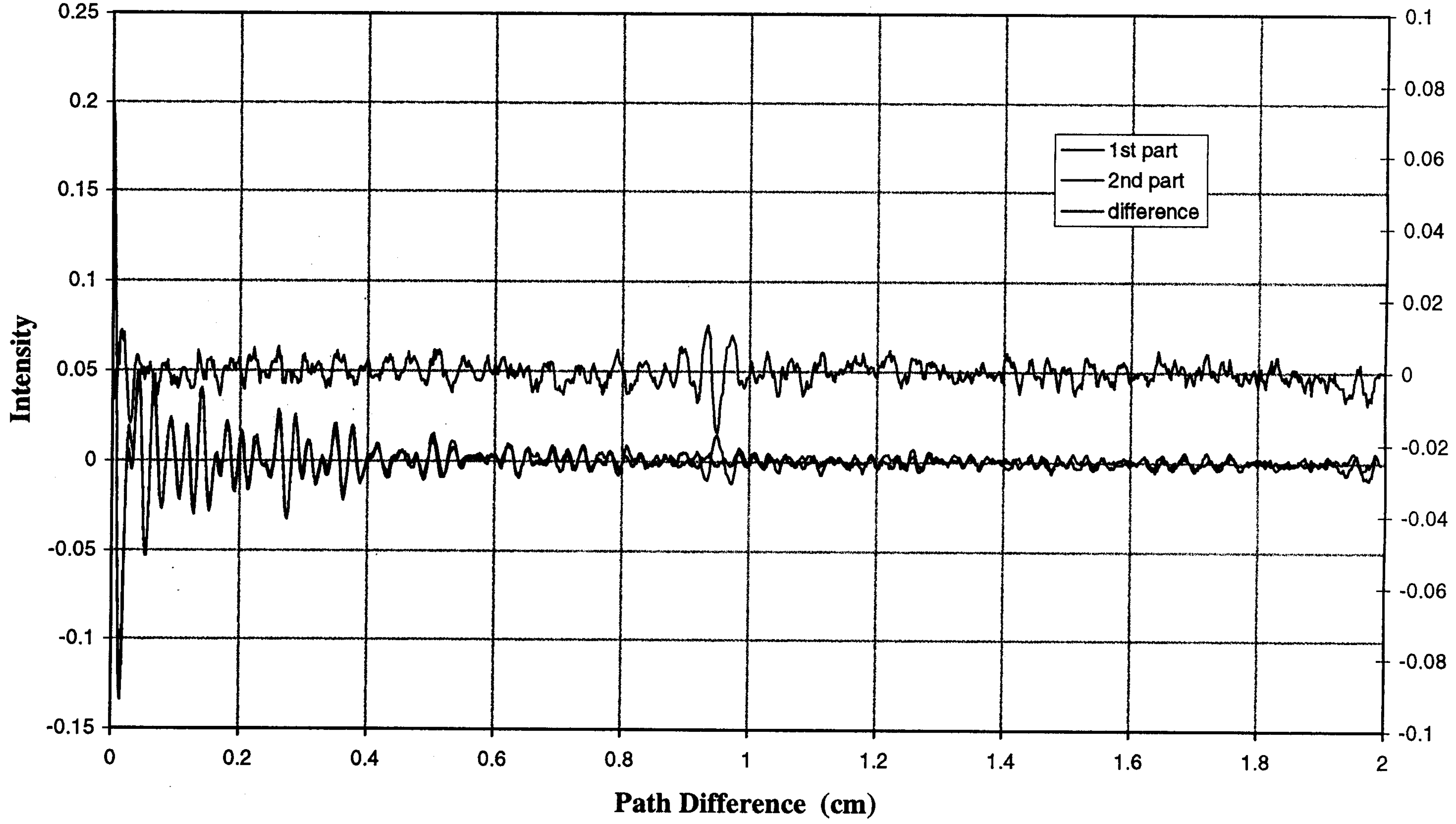

FTS beam divider transmission
FTS beam divider no917 22: 1:1999
FTS beam divider no916 22: 1:1999
Transmission
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
5
15
25
35
45
55
65
75
85
95
Wavenumbers [cm-1]

Spire FTS - average of 10 - 2 second scans
Intensity
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Data Points
average

Spire FTS Liquid Nitrogen source versus ambient (Alternate Ports)

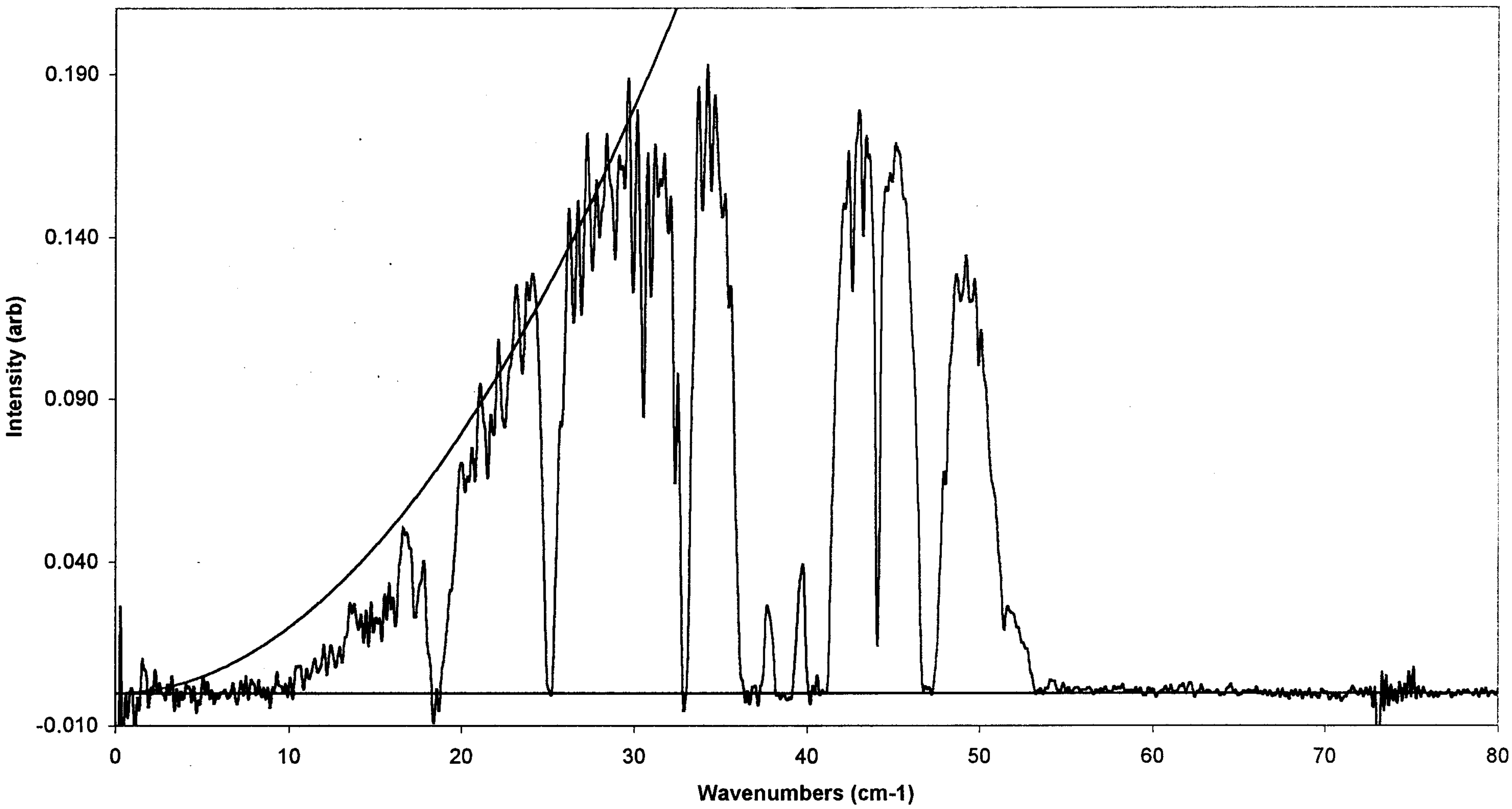



Spire FTS
spire_1_warm
spire_1_cold
spire_2_cold
spire_3_cold
spire_4_cold
average
spire_1_beam
spire_1_null
Intensity
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
800
850
900
950
1000
1050
1100
1150
1200
Data Points

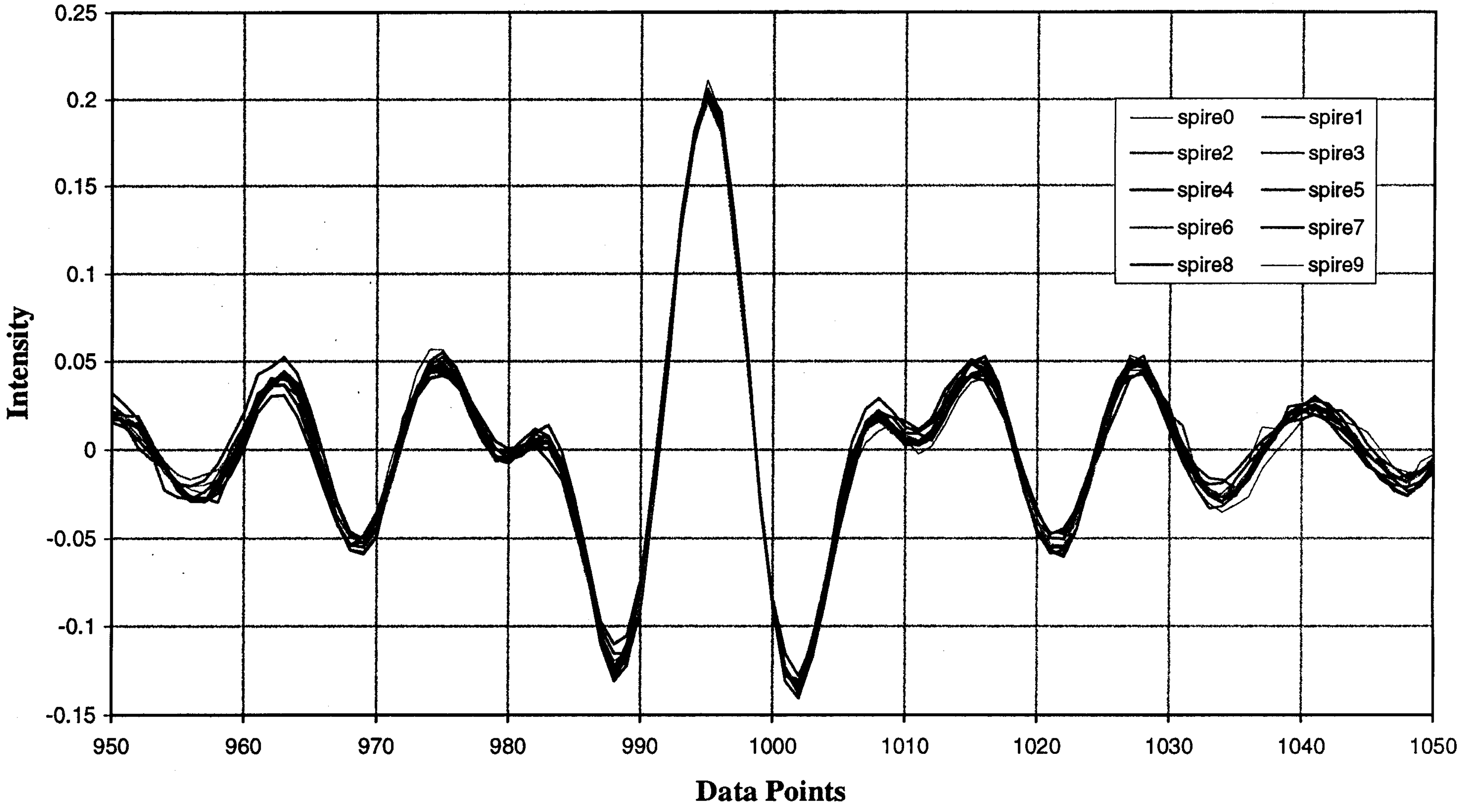


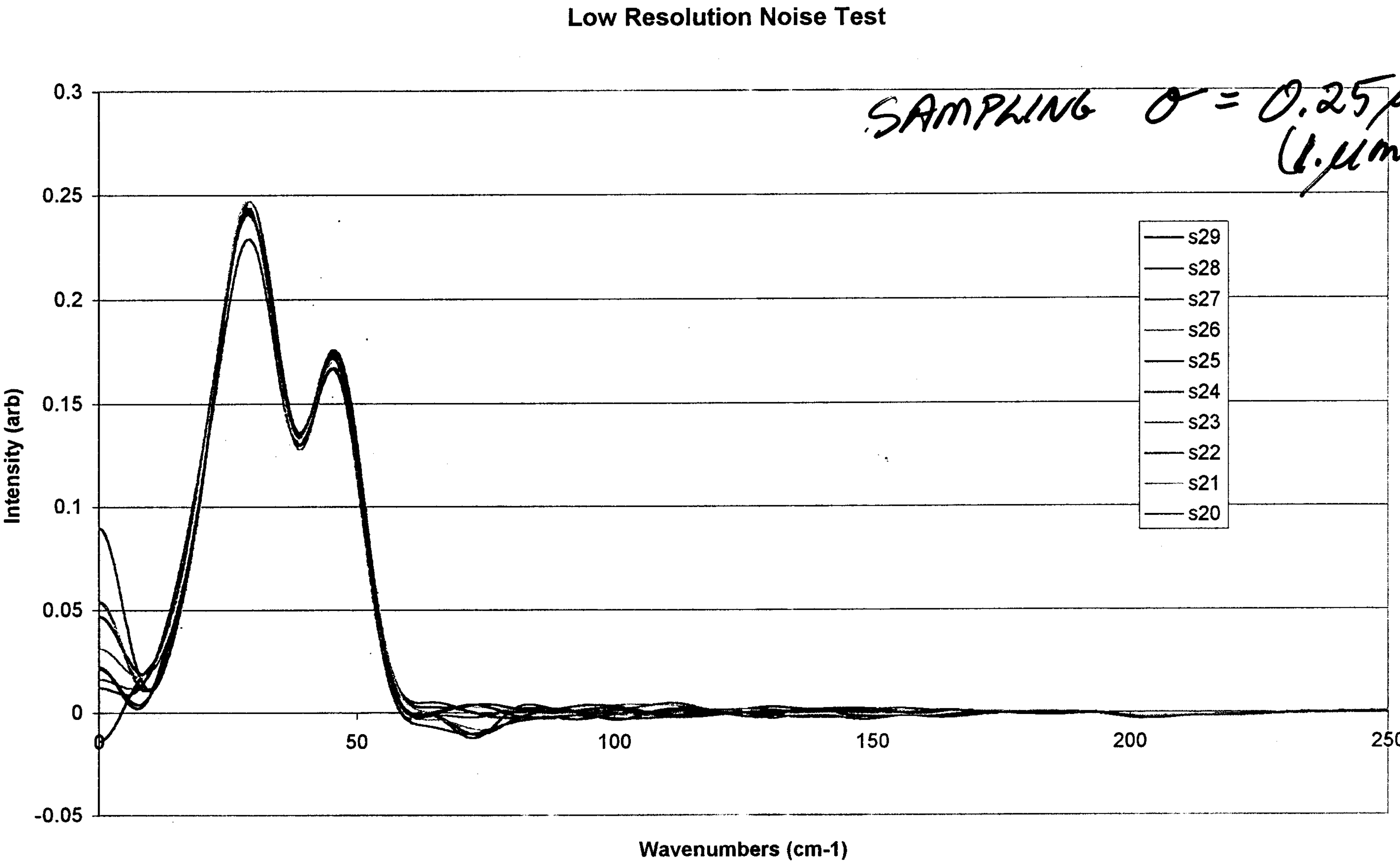
Spire FTS asymmetry in Mirroring

High Resolution Test Spectrum

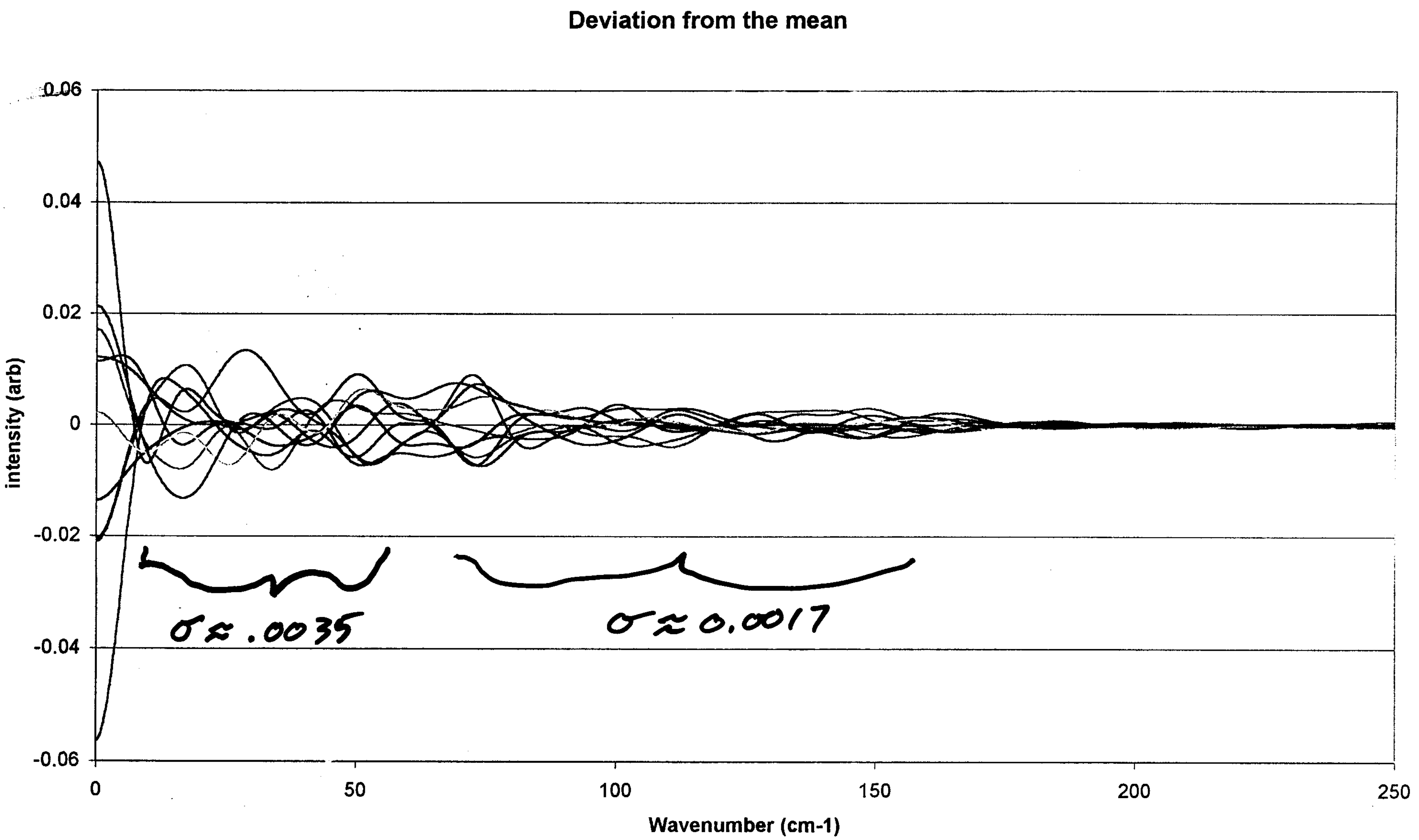


Spire FTS - overlay of raw 2 second scans

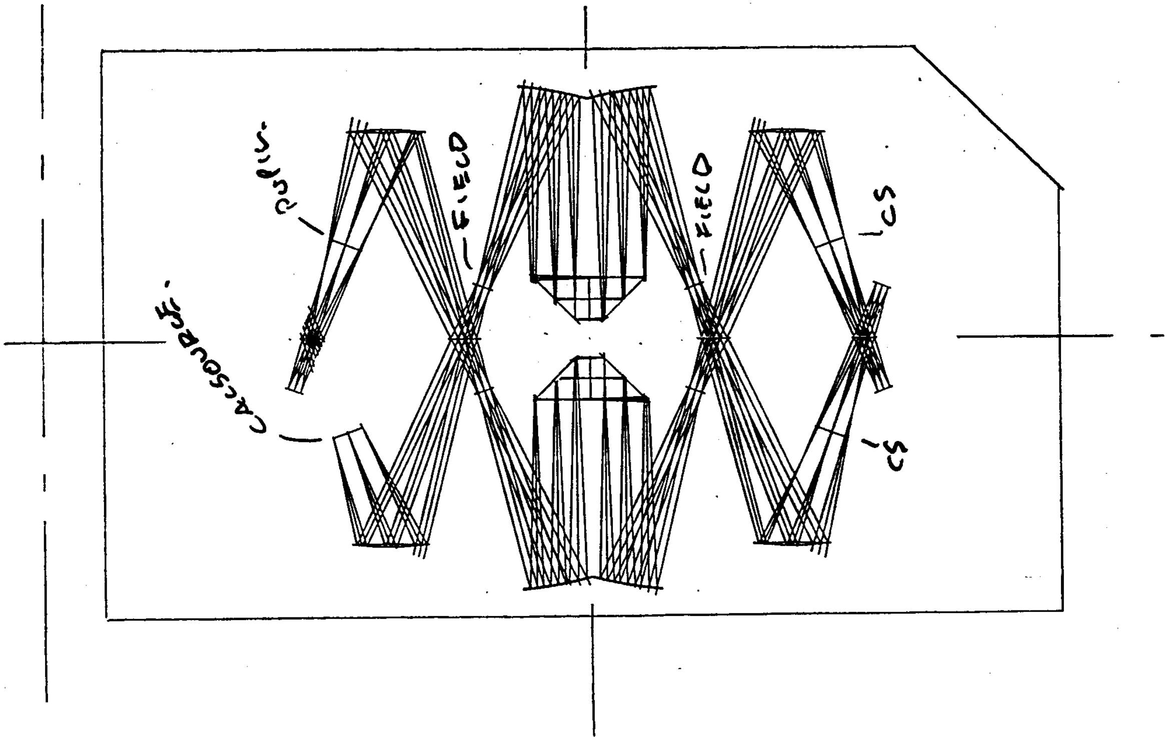




SAMPLING $\sigma = 0.25 \mu m$
(1.µm OPD)



Deviation from the mean


CA-SOURCE.
PUPIL.
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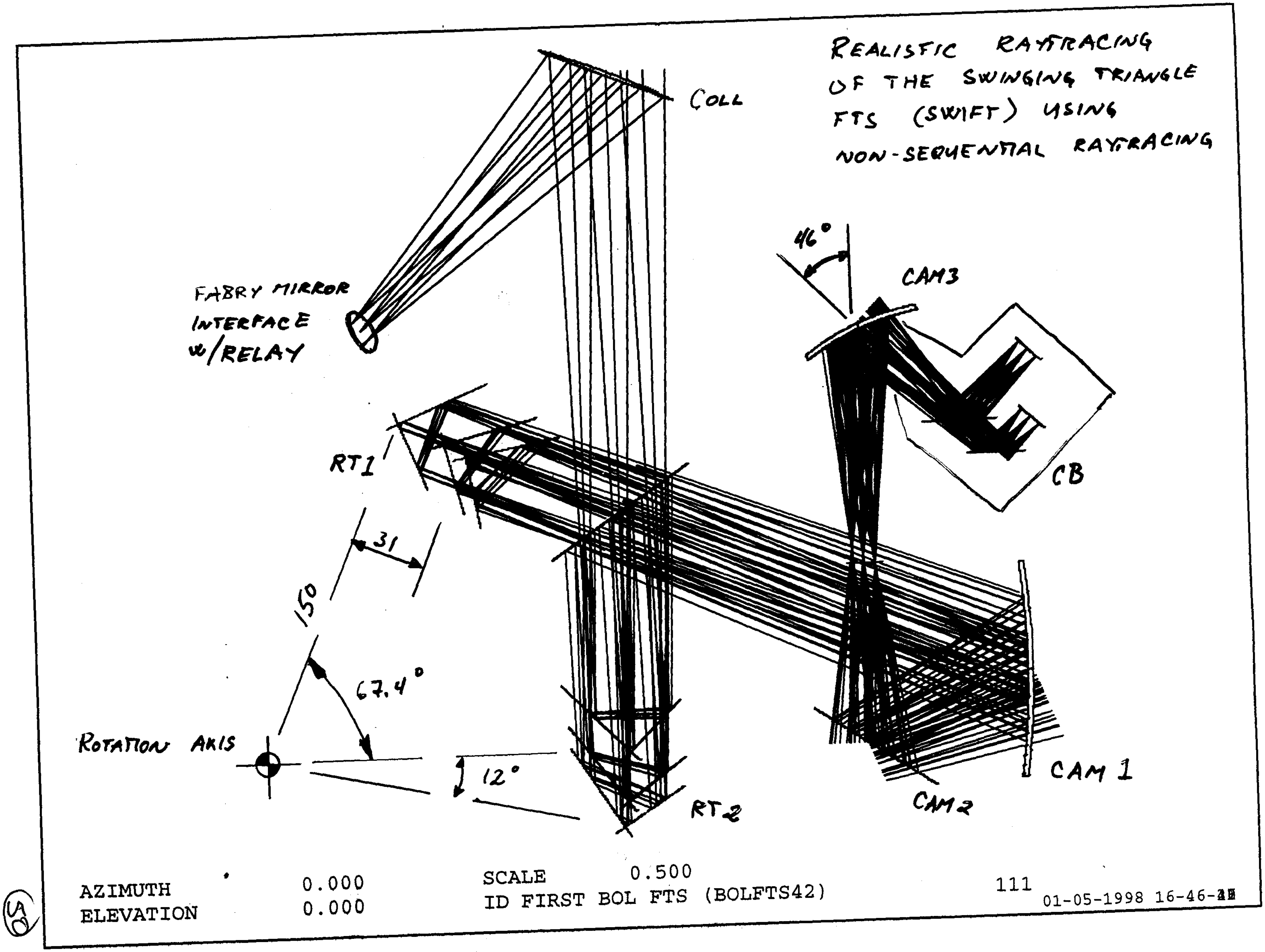


REALISTIC RAYTRACING
OF THE SWINGING TRIANGLE
FTS (SWIFT) USING
NON-SEQUENTIAL RAYTRACING

22/01/99

Evaluation of a Moiré fringes position transducer

G.Michel
DESPA / MEUDON OBSERVATORY

1.1 Introduction :

Positions tranducers of the LVDT type have been investigated for sampling the SPIRE interferograms. Their resolution seems marginal for the application, especially at low resolution. To overcome that difficulty we can think of using an additional short range LVDT to benefit of its increased sensitivity. This configuration with two LVDTs seems barely adequate. At this point, it is interesting to evaluate the second possible choice, the Moiré-fringes linear transducer.
The sampling with Moiré and LVDT transducer is rather different. With the LVDT the interferogram is ' time sampled ' but with the Moiré it is position or opd sampled (at this long wavelength position and opd are likely similar).

A Moiré fringes commercial transducer has been tested on the same CASSINI - CIRS test bench used for the LVDT measurement. This Moiré transducer has been piggybacked on one end of the mechanism shaft, the other end has a flat mirror so we can monitor at the same time the displacement as measured by the laser interferometer and the Moiré transducer.
For this operation the carriage is phase locked onto the laser reference fringes, the average velocity is .3 mm.s-1 .

1.2 Measurements carried out with a Moiré fringes transducer :

The transducer, manufactured by Heidenhain (model LIP 403 A - range 2 cm), includes two diffraction gratings and an optical head. The diffraction gratings are made by a photographic process on a ZERODUR carrier. A thin layer of chromium is then deposited. The grating period is 4 microns (250 grooves / mm) and the output fringes have a period of 2 microns.
The model tested does not have a side track with fiducial marks but this is available on other models.

The resolution depends of the S/N of the fringe signal.
The Moiré fringes have a S/N of 1500. This gives a resolution of :

$$\Delta x = N/S \,.\, \lambda / (2.\pi) = 2.\ 10\text{-}4 \text{ microns} \qquad (\lambda = 2 \text{ microns})$$

This is to be compared with what we have with our solid state laser interferometer - S/N = 400

$$\Delta x = N/S \,.\, \lambda / (2.\pi) = 3.\ 10\text{-}4 \text{ microns} \qquad (\lambda = 0.78 \text{ microns})$$

A difference to remember is that the the laser interferometer is perfectly linear and the Moiré transducer has a residual non linearity of 5. 10-6 . Over the 2 cm displacement capability of this transducer this corresponds to a deviation of 20000 x 5.10-6 = .1 micron . If we consider the displacement of 3 mm of our actual test this gives a deviation of .1 x 3/20 = .015 micron.

To measure the sampling jitter with the Moiré, one proceeds as follows :
The Moiré fringes are sampled with the laser interferometer. Taking each zero crossing of the laser fringes, the sampling step is λ /2 or .39 micron opd . This gives a number of samples per Moiré fringe of 4 / 0.39 =10.25.

(51)

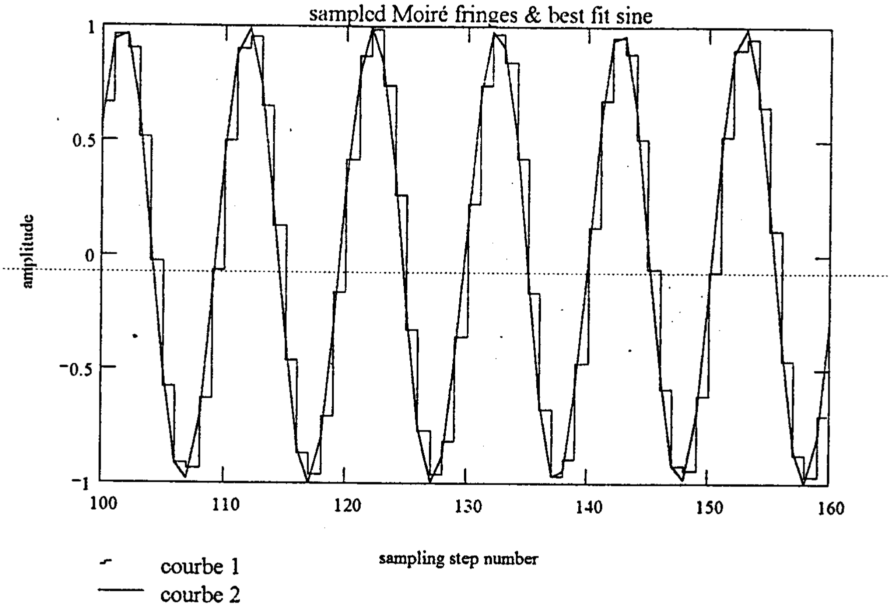


fig 1 :Sampling the Moiré fringe pattern with the laser interferometer :
A file of 16K samples is recorded, the opd is 6.24 mm . This shows one section of that file. The Moiré fringes are best fitted by a sine wave taken later as reference. The sampling error is then deducted by taking the difference between the arguments of the Moiré fringes and the reference. The result is scaled in microns .

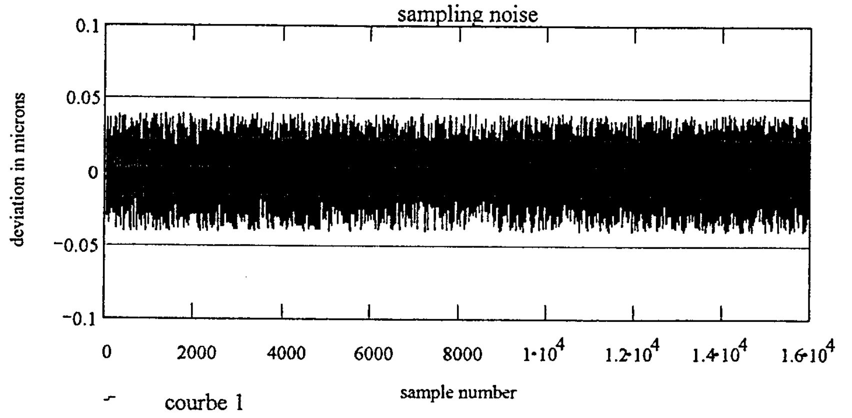


fig 2 : Sampling jitter :
The value is **.01 microns rms.**
This is to compare to the ultimate resolution of **.0002 microns rms** considering only the S/N of the fringe pattern.
Other effects like the accuracy of the zero crossing detector and velocity fluctuations can very rapidly degrade the performances when we are looking for nm resolutions.
In any case sampling errors of .015 microns rms are better by a factor 50 over that obtained with the LVDT previously tested.

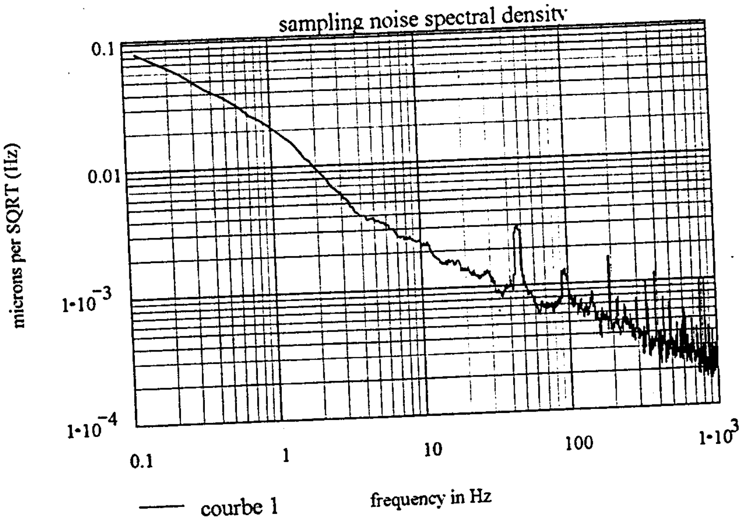


fig 3 : Noise spectral density :
The first peaks correspond to a residual @ 50 Hz and 100Hz .

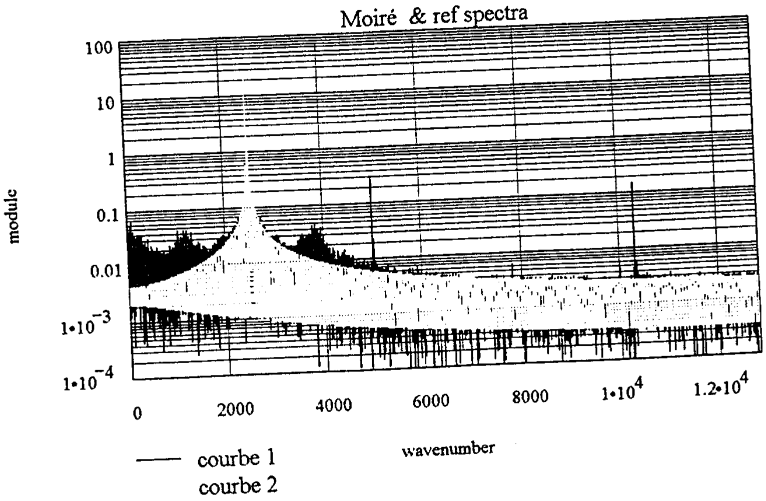


fig 4 : This is the comparaison of the Moiré fringes spectrum and reference spectrum. The main line is of course @ 2500 cm-1 . We have a ghost @ 5000 cm-1 . Since we are working with a narrow spectral bandwith as compared to 2500 cm-1 this should not be of a concern.

(53)

1.3 Comparison of the LVDT and Moiré transducers :

	LVDT	Moiré
resolution	.5 microns (*)	. 01 microns
linearity	2.5.10-3	5. 10-6
type of sampling	time sampling	position (opd) sampling
susceptibility to pick-up	large	small
alignment	not critical	not critical
space qualified	yes	no
fiducial mark	no	yes

(*) the space qualified LVDT (Schaewitz) is bulky and does not have quite the sensitivity of the one tested with the CIRS prototype . **So we might have to develop an LVDT especially adapted to our needs if we want to keep the .7 microns rms expected for our extrapolated simulation.**

Advantage of the Moiré vs LVDT :

- one single transducer
- very good resolution (no need to oversample to improve the resolution)
- no linearization needed
- choice of the sampling step (min 2 microns using each zero crossing of the Moiré fringes)

Drawback of the Moiré vs LVDT :

The very serious drawback is that we have to carry the space qualification at 4K . The source, an LED, and the 2 or 3 output of the optical head have to be fibered between the warm electronics compartment and the cryostat at 4K. This is certainly feasible but it will require some development to find a practical way to reach the mechanism area - (fiber connectors feed through) -

The gratings of the Moiré have to be tested to survive the cooling. We can purchase from the manufacturer (Heidenhain) the gratings but we will have to keep on our side the qualification at cold with no possible feedback if it fails.

A smaller company producing optical encoders for the military and the CNES agency would be a better choice. Contacts with this company are in progress.

1.4 Conclusion :

The use of a Moiré fringes transducer would certainly lead to a clean way of doing Fourier spectroscopy like sampling according to the path difference with a very good resolution and an almost negligible non linearity.

At the resolution of .01 cm-1, LVDTs will certainly offer no safety margin. Besides we have to take into account other sources of perturbations like pick-up and vibrations aboard the spacecraft.

The serious disadvantage of the Moiré is that the space qualification is more demanding but feasible and worth to be thoroughly investigated at this time in the project.

(54)

SPIRE interferometer parameters relevant to the selection of a transducer

resolution 1000 @ 50 cm-1 (200 µm) Δσ = 0.05 cm-1 (no apodization)

for a resolution of Δσ = 0.05 cm-1 , the maximum opd is :
opd max = 1 / 2*Δσ = 1 / 2* 0.05 = 10 cm (this for a single **sided interferogram**)

with the Max Zehnder interferometer including two rooftops opposed mounted on the same translation platform (cf P.Ade design) the opd is 4 times the displacement. Therefore the translation to achieve is :

displacement = 10 / 4 = 2.5 cm

This gives the transducer range. So far our measurements with the CIRS LVDT have been made for a displacement of 1.25 cm and extrapolated for a displacement of 5 cm.

LVDTs of the SIMULATION (Schaewitz)
300 HR on the CIRS prototype - 1000 HR for the extrapolated simulation

	range mm	sensitivity mV/V/mm	body g	core g	body mm	core mm
300 HR	±7.5	56	77	10	82	50
1000 HR	±25	16	126	21	168	102

For the extrapolation the loss in sensitivity is 3.5 (56/16).
In the real case we would rather need a model 500 HR of sensitivity 28/mV/V/mm.
To be consistent we have to multiply the S/N of the simulation by a factor of 3.5 / 2 = 1.75.

Result of the simulation with an LVDT
displacement = 1.25 cm , extrapolated to 5 cm
simple Michelson , double sided interferogram

displacement	5 cm
opd max	5 cm
resolution (1/2*opdmax)	.1 cm-1 (no apodization)
oversampling	16
S/N	1000 (apodized)

Sampling at the Nyquist rate the S/N = 1000 / √ 8 = 353

For a Mac Zehnder and single sided interferogram as defined above, the transducer range is reduced by a factor 2 and the sampling noise decreased by a factor 1.75 . The previous S/N is multiplied by 1.75 / √ 2 = 1.237 . The √ 2 comes from the increased resolution by a factor 2.

displacement	2.5 cm
opd max	10 cm
resolution (1/2*opdmax)	.05 cm-1 (no apodization)
oversampling	16
S/N	1237 (apodized)

Sampling at the Nyquist rate the S/N = 1237 / √ 8 =437

(55)

Available Schaewitz transducers

Schaewitz LVDTs

standard

	range mm	sensitivity mV/V/mm	body g	core g	body mm	core mm
500 HR	±12.5	28	109	18	140	88
100 HR	±2.5	180	48	6	46	33

Φext= 25.4 mm Φint= 9.5 mm Φcore= 6.3mm

miniature

	range mm	sensitivity mV/V/mm	body g	core g	body mm	core mm
500 MHR	±12.5	70	17	1.6	83	50
100 MHR	±2.5	100	6	0.5	25.4	15.7

Φext= 9.5 mm Φint= 3.18 mm Φcore= 2.74 mm

cryogenic

	range mm	sensitivity mV/V/mm	body g	core g	body mm	core mm
500 XS-Z	±12.5	16	360	8	142	76
100 XS-Z	±2.5	51	270	4	64	34

Φext= 25.4 mm Φint= 4.93 mm Φcore= 4.5 mm

Moiré position transducer (Heidenhain LIP 403 A)

range	2mm
resolution	0.01 microns
non linearity	+/- 2.5 10-6
grove spacing	4 microns
signal period	2 microns
optical head	25 g
scale	5g

(56)

[redacted]

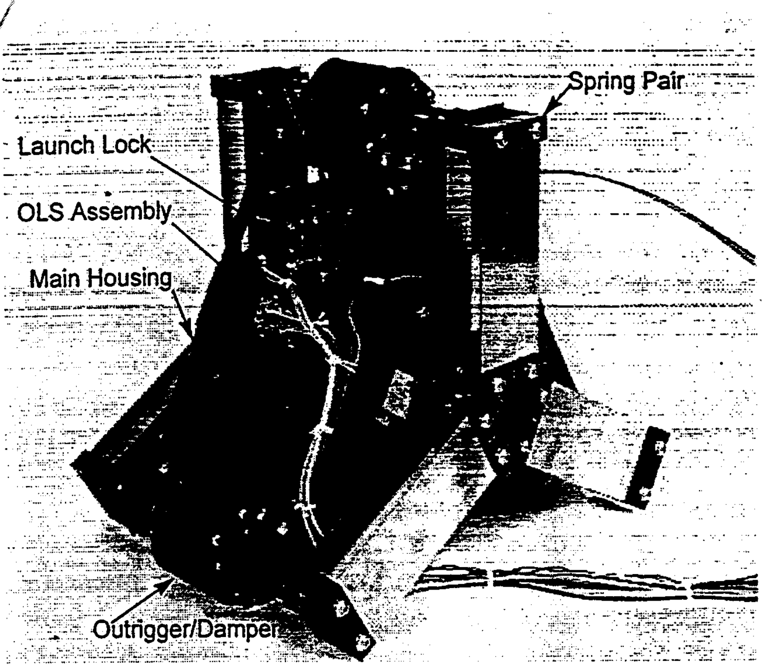


Figure-3 Engineering Model Scan Mechanism

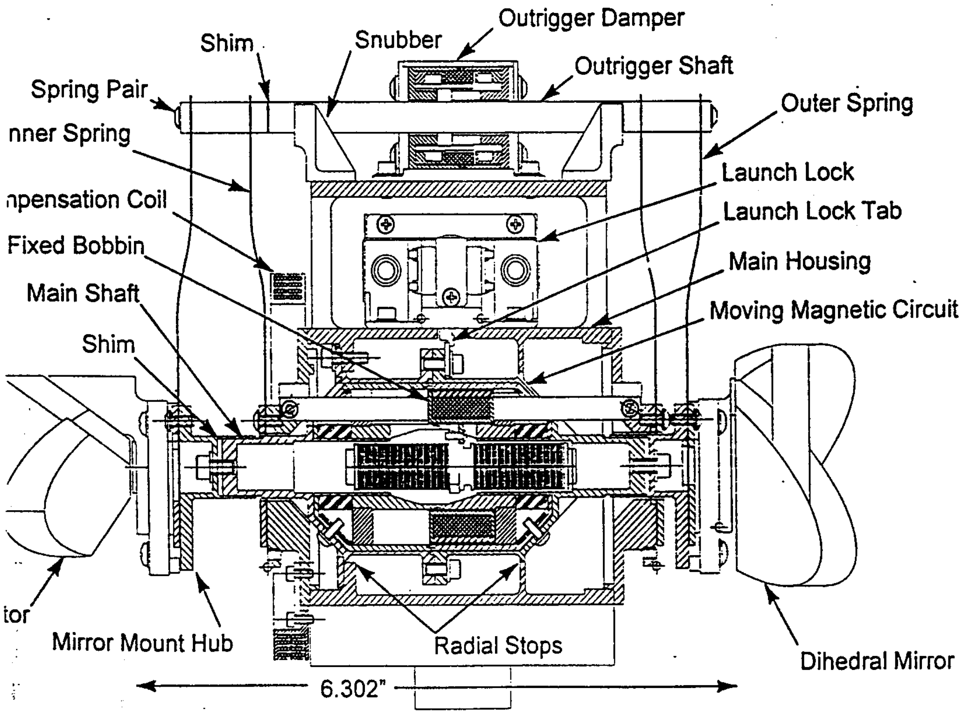


Figure-4 Scan Mechanism In Locked Configuration

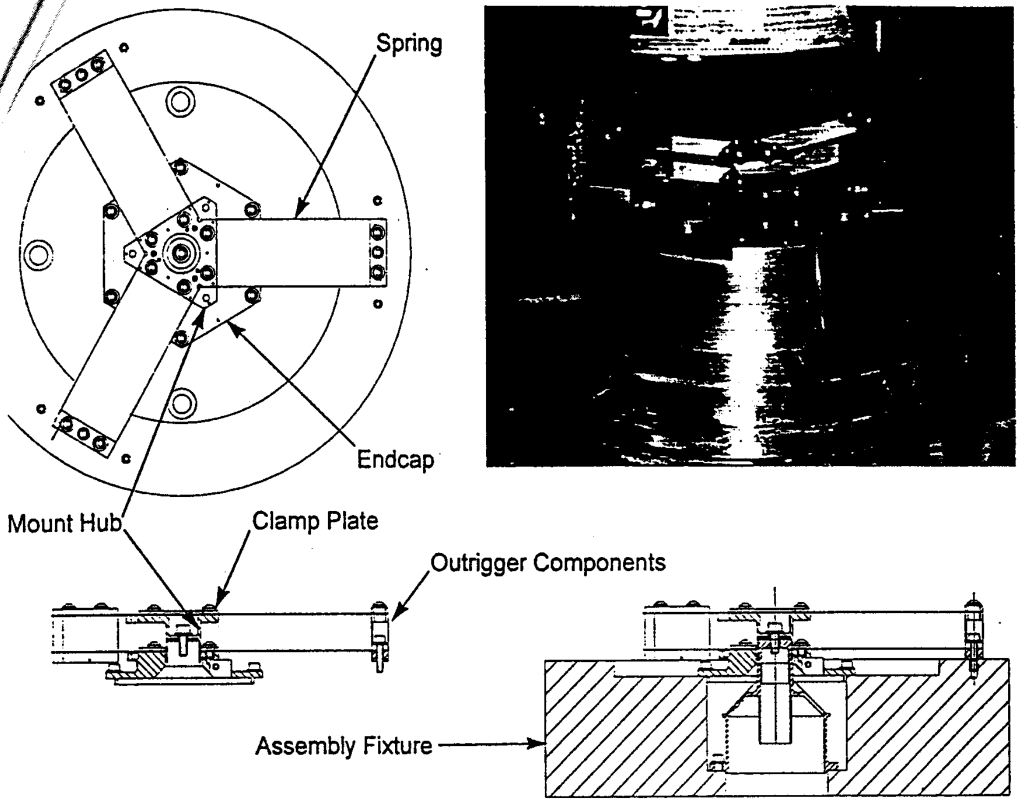


Figure-5 Spring Pair Assembly

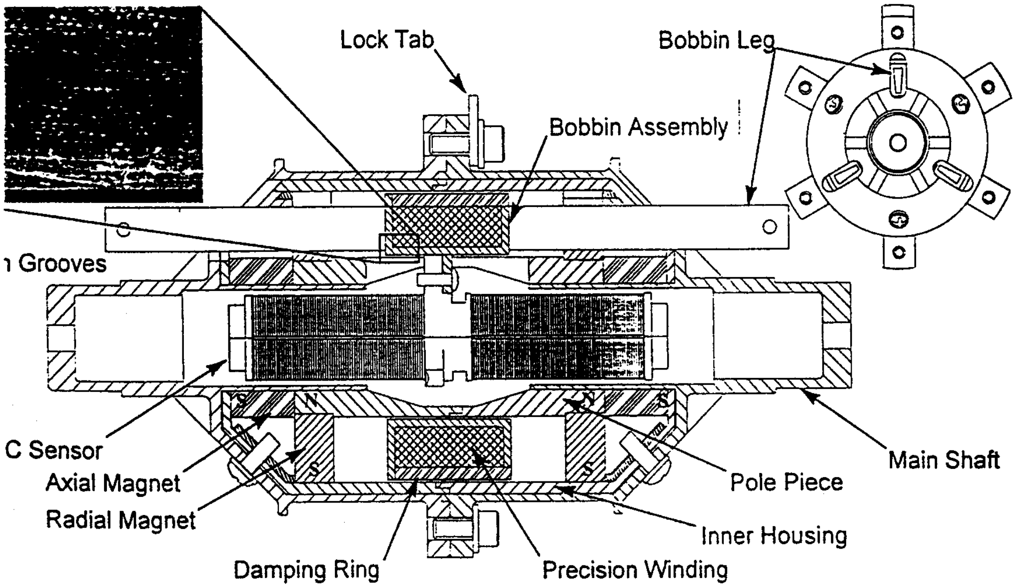
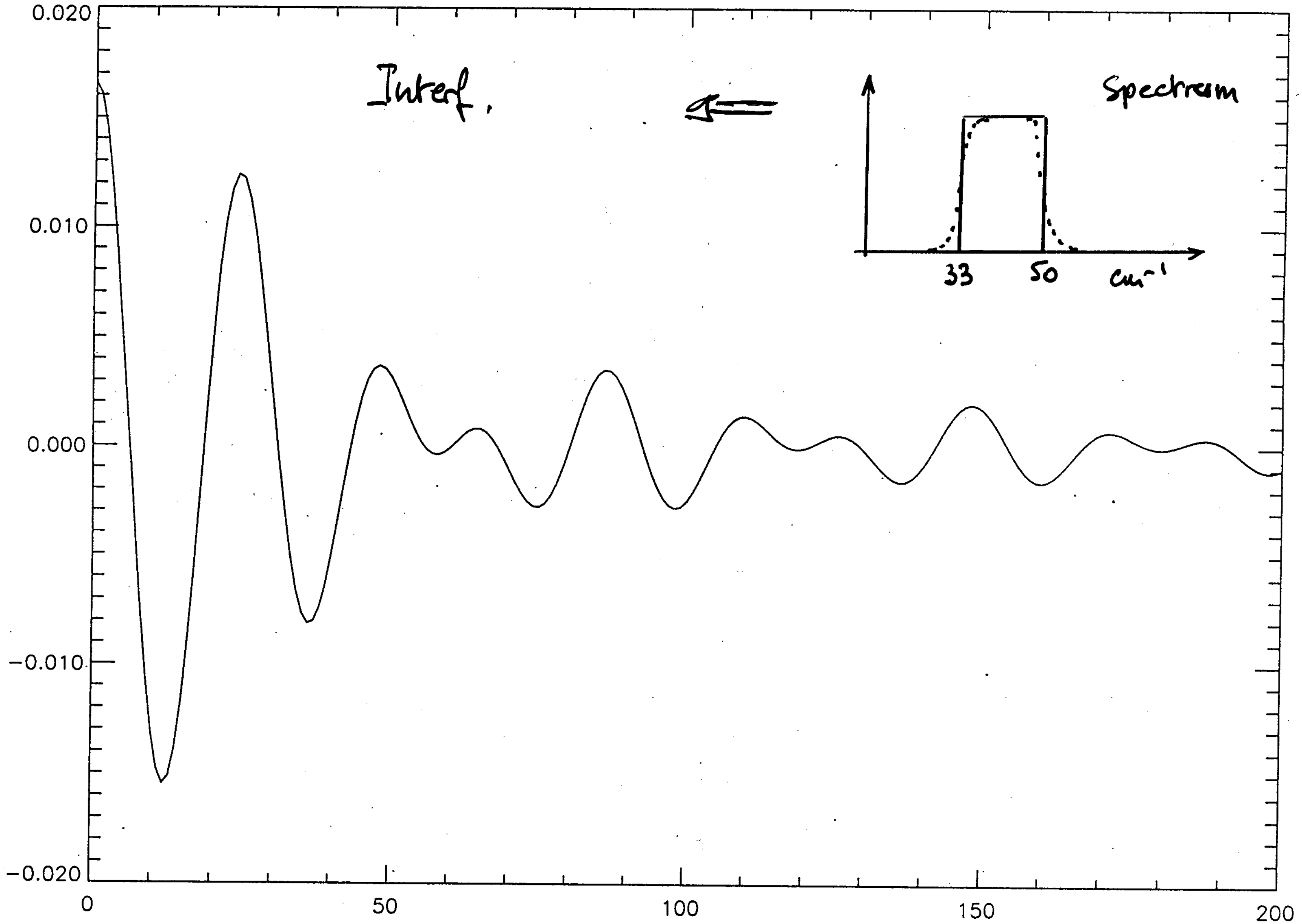
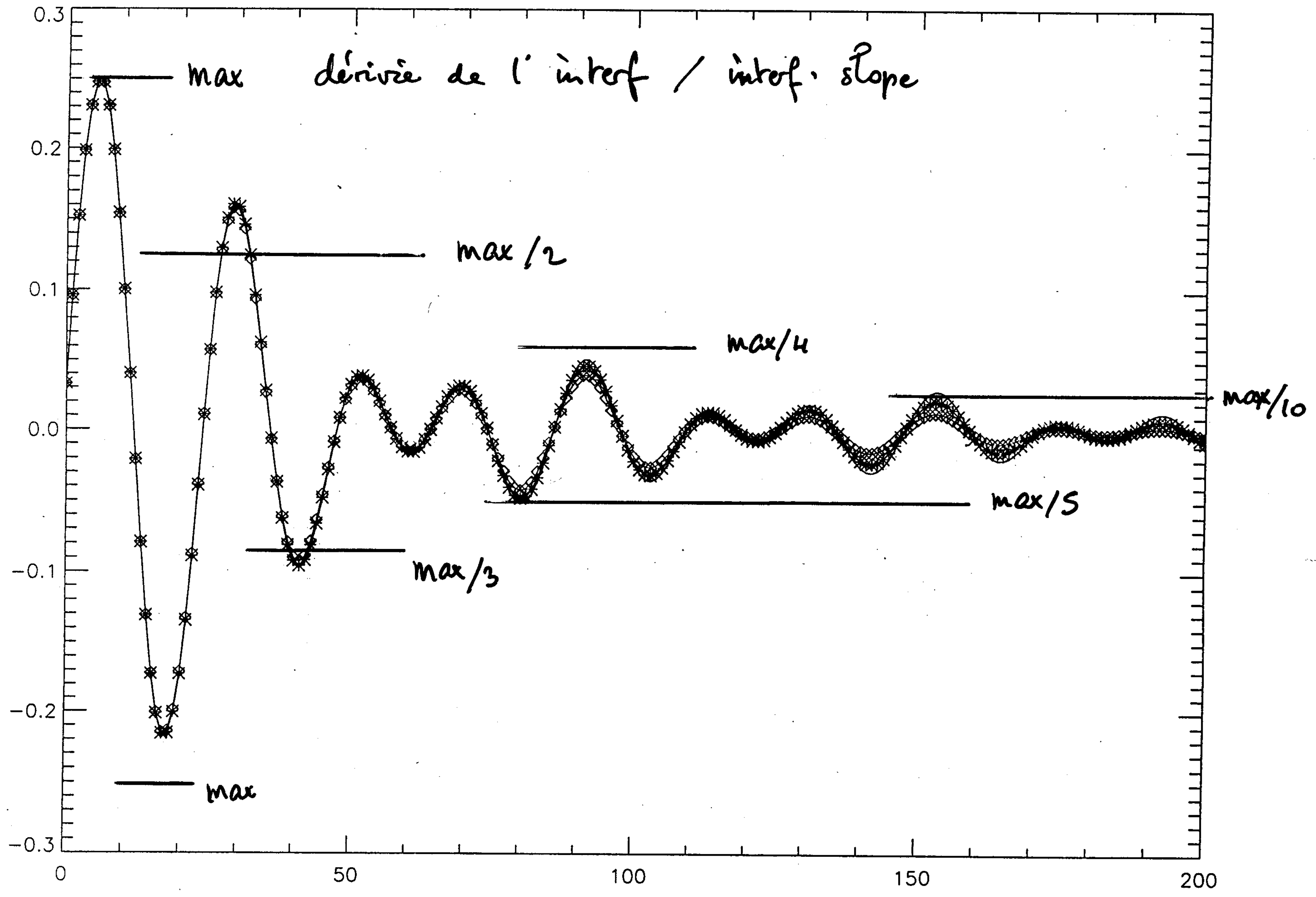
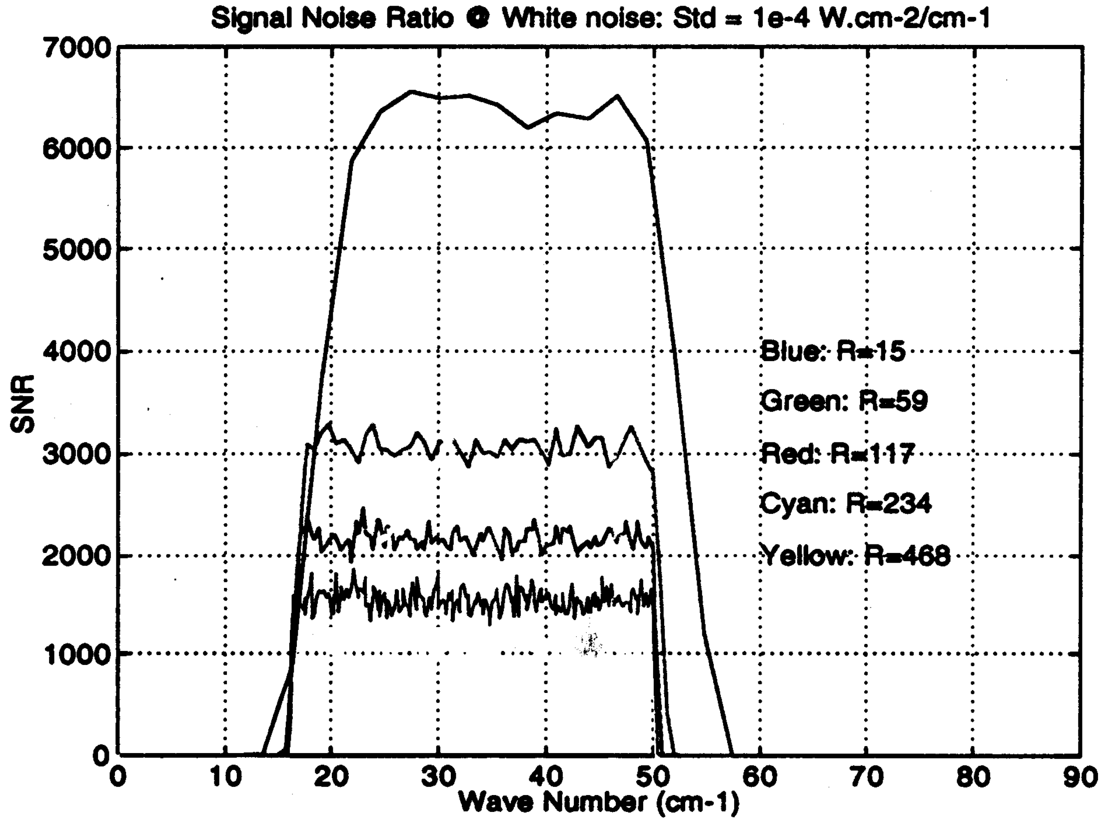


Figure-6 Actuator Assembly

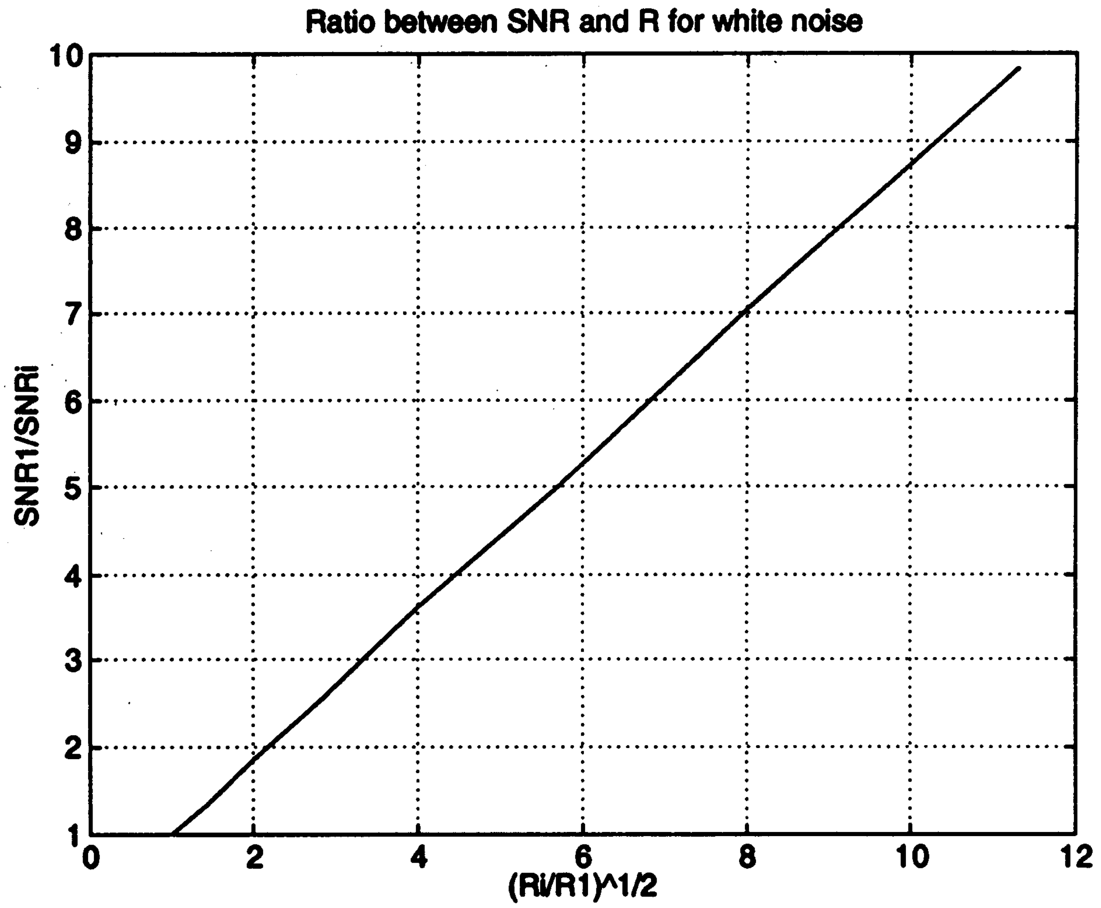

Interf.
Spectrum
33
50
cm^{-1}
0.020
0.010
0.000
−0.010
−0.020
0
50
100
150
200


max
dérivée de l' interf / interf. slope
max/2
max/4
max/10
max/5
max/3
max
0.3
0.2
0.1
0.0
−0.1
−0.2
−0.3
0
50
100
150
200

SIGNAL NOISE RATIO FOR WHITE NOISE

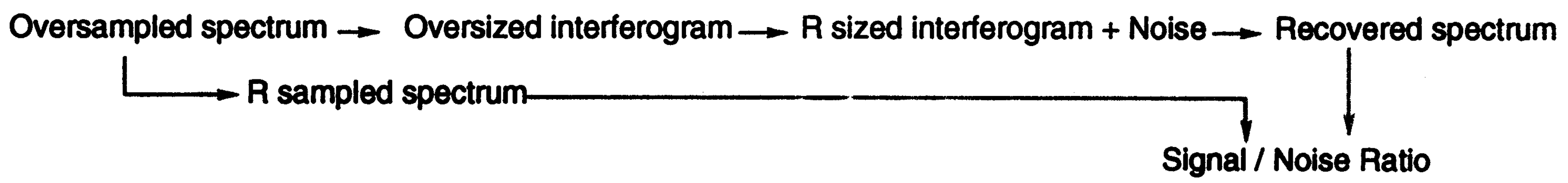


Signal Noise Ratio @ White noise: Std = 1e-4 W.cm-2/cm-1



CONCLUSION: SNR is in inverse proportion of the R ratio square root

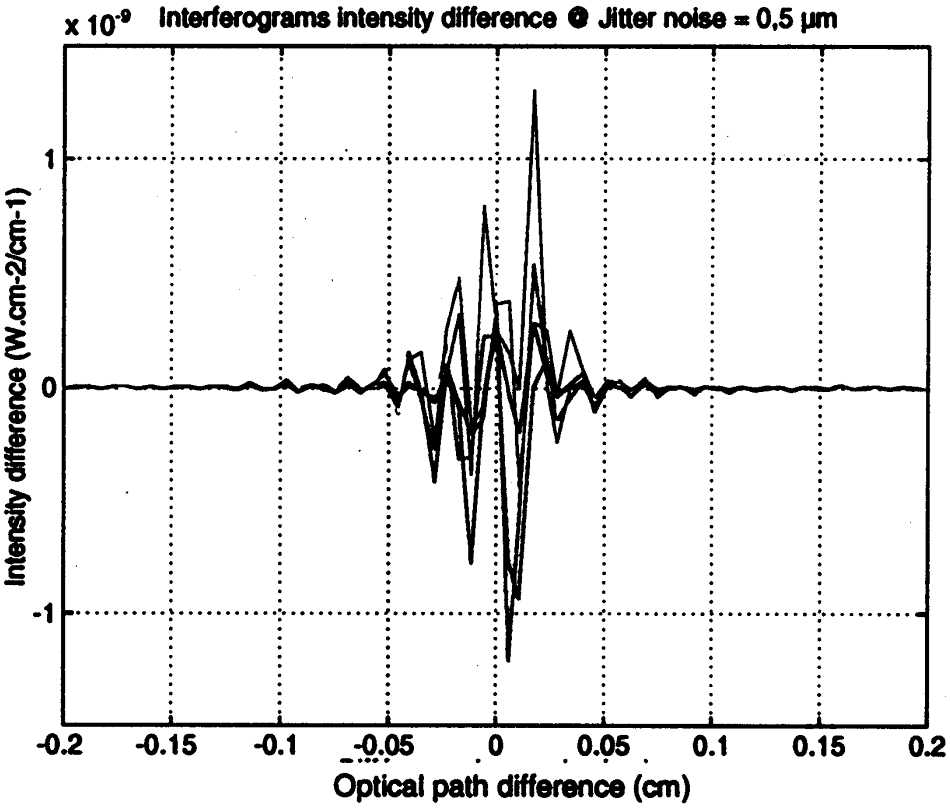
JITTER NOISE: INTERFEROGRAMS DIFFERENCE



Oversampled spectrum → Oversized interferogram → R sized interferogram + Noise → Recovered spectrum

→ R sampled spectrum

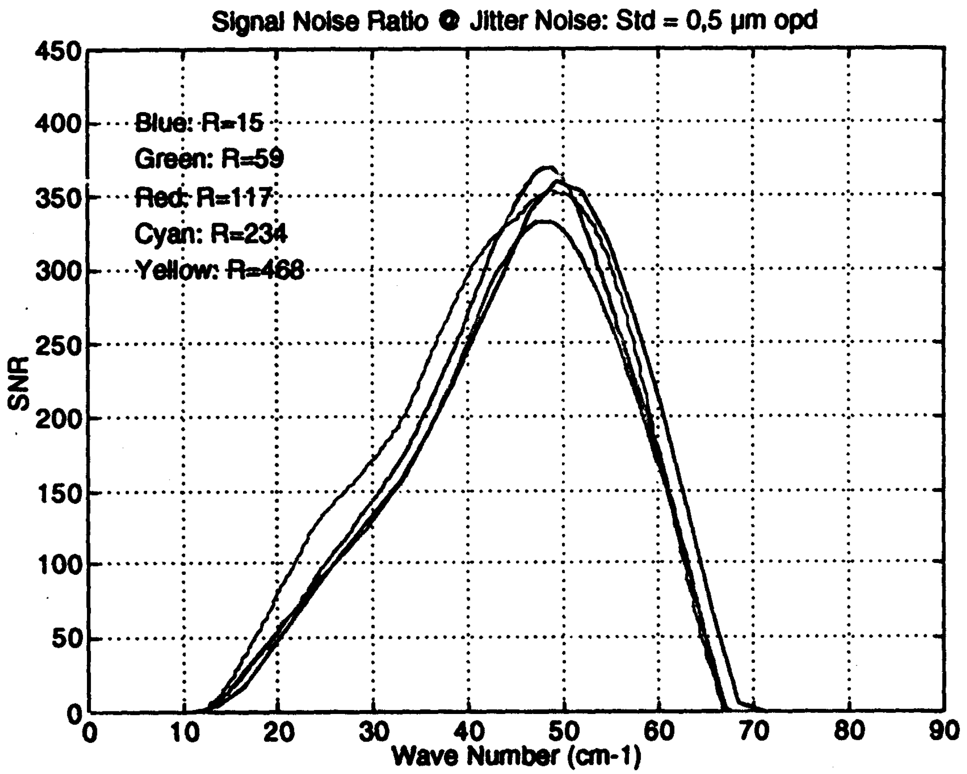
Signal / Noise Ratio



Error max: Std = 0.5 µm in opd

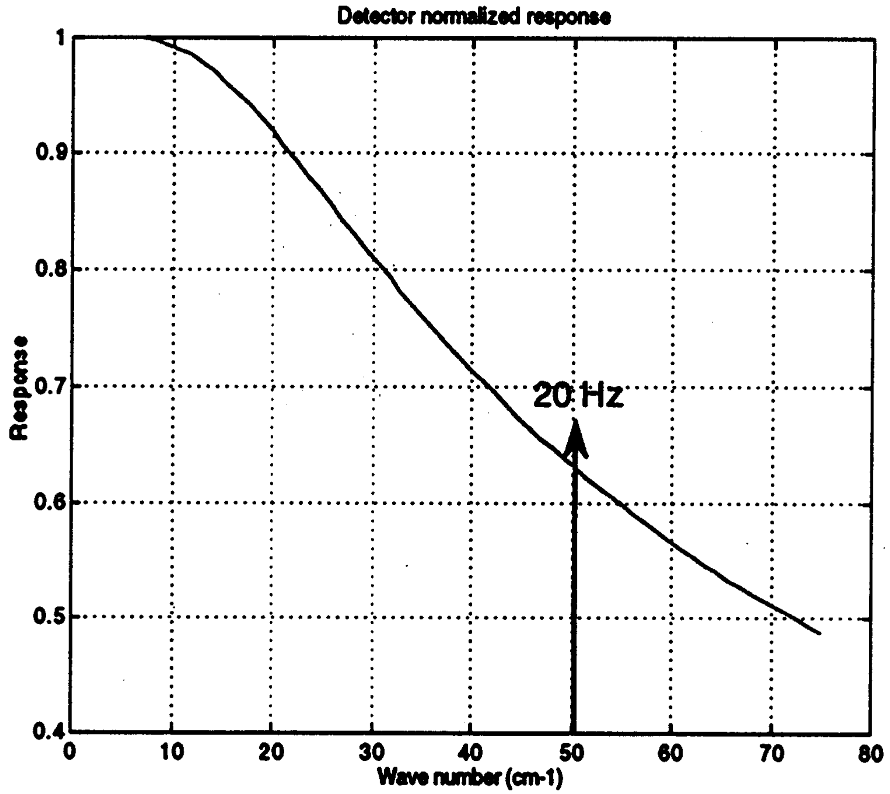
The most important parameter is the interferogram slope

SIGNAL / NOISE RATIO FOR THE JITTER NOISE



CONCLUSION: The SNR is independent of the spectral resolution

DETECTOR NORMALIZED RESPONSE

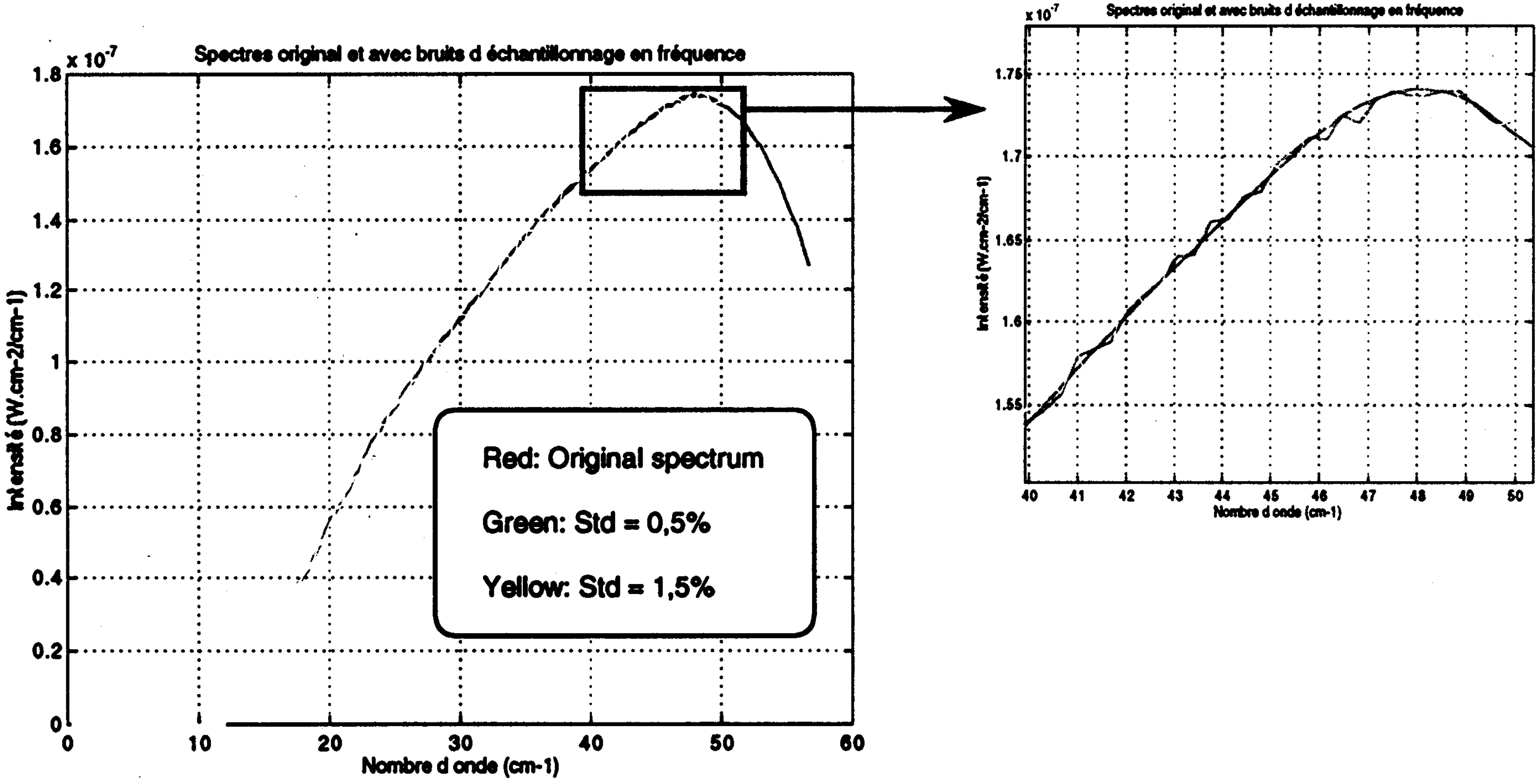


Cut off frequency: Fc=20 Hz

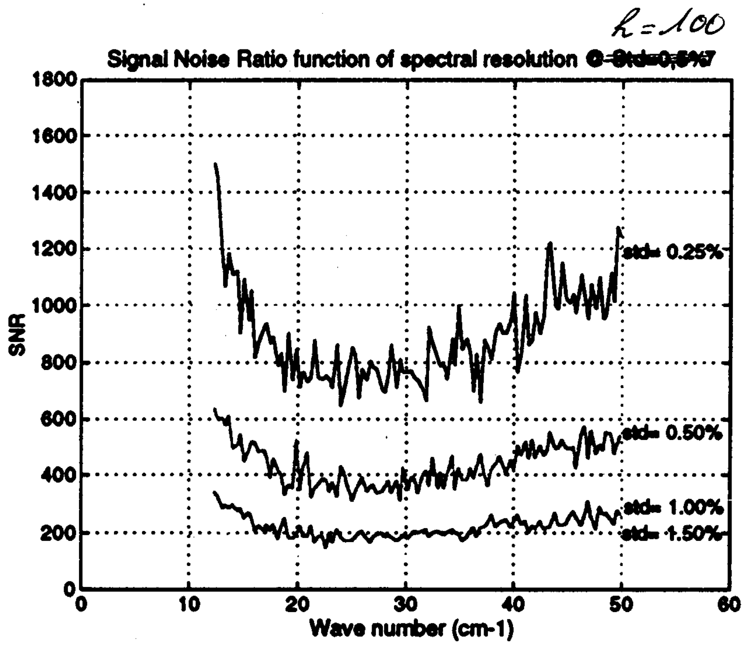
Max. Optical frequency = 50 cm-1

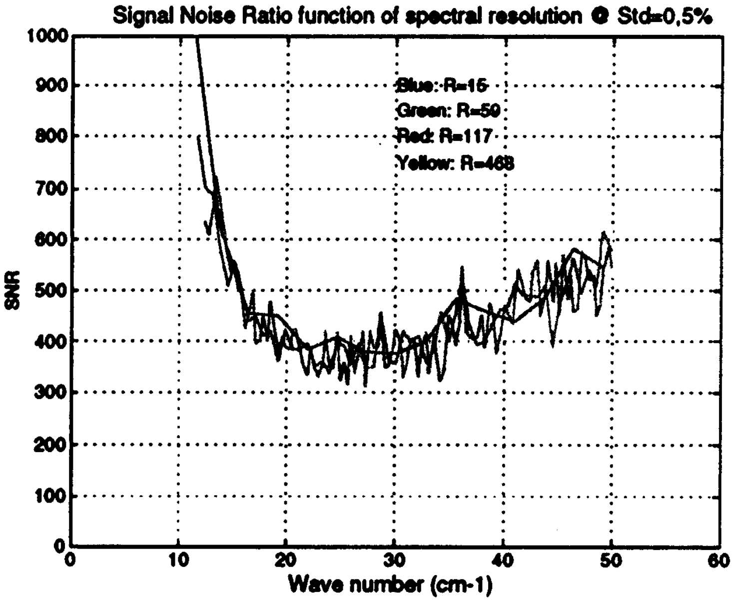
Velocity fluctuations
+
Response slope
=
Amplitude errors

FREQUENCY SAMPLING NOISE



SIGNAL / NOISE RATIO : FREQUENCY SAMPLING NOISE



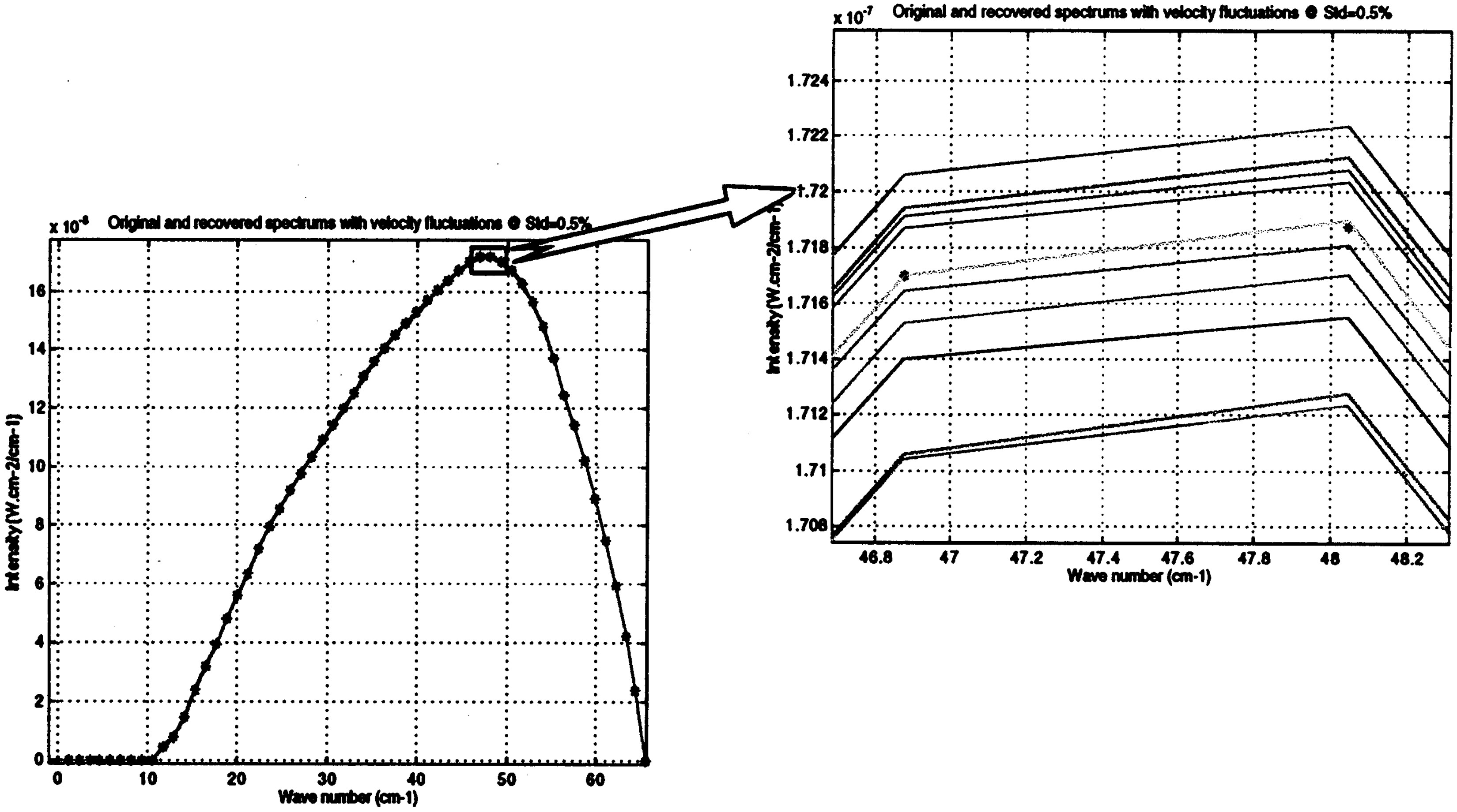


CONCLSIONS: The SNR is minimum at the largest slope position of the detector response

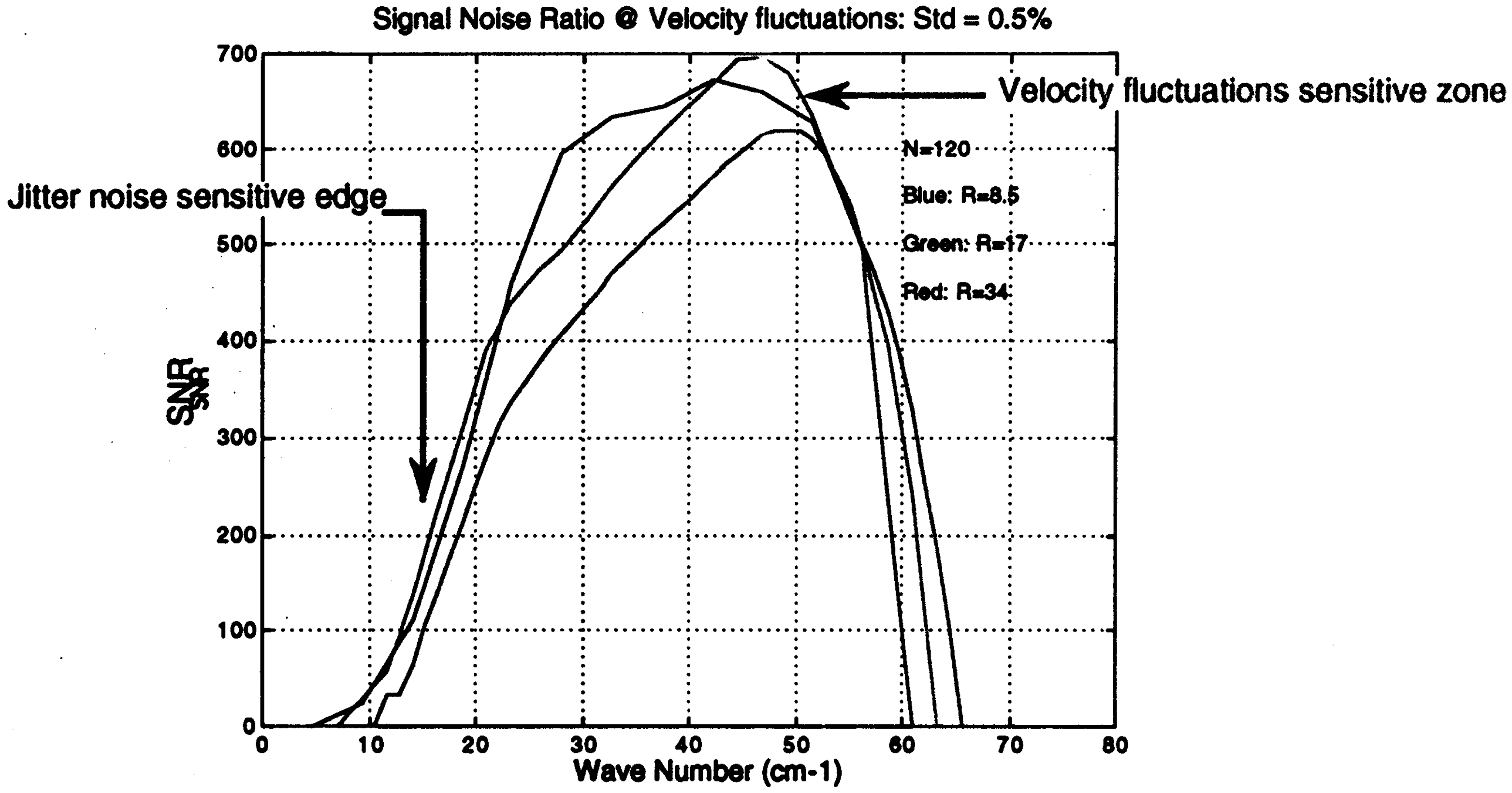
Similar to the jitter noise the SNR, here, is not correlated to the spectral resolution

For 0.5% velocity fluctuations we obtain the same SNR than 0.5µm jitter noise

RECOVERED SPECTRUMS WITH VELOCITY FLUCTUATIONS



SIGNAL NOISE RATIO: VELOCITY FLUCTUATIONS



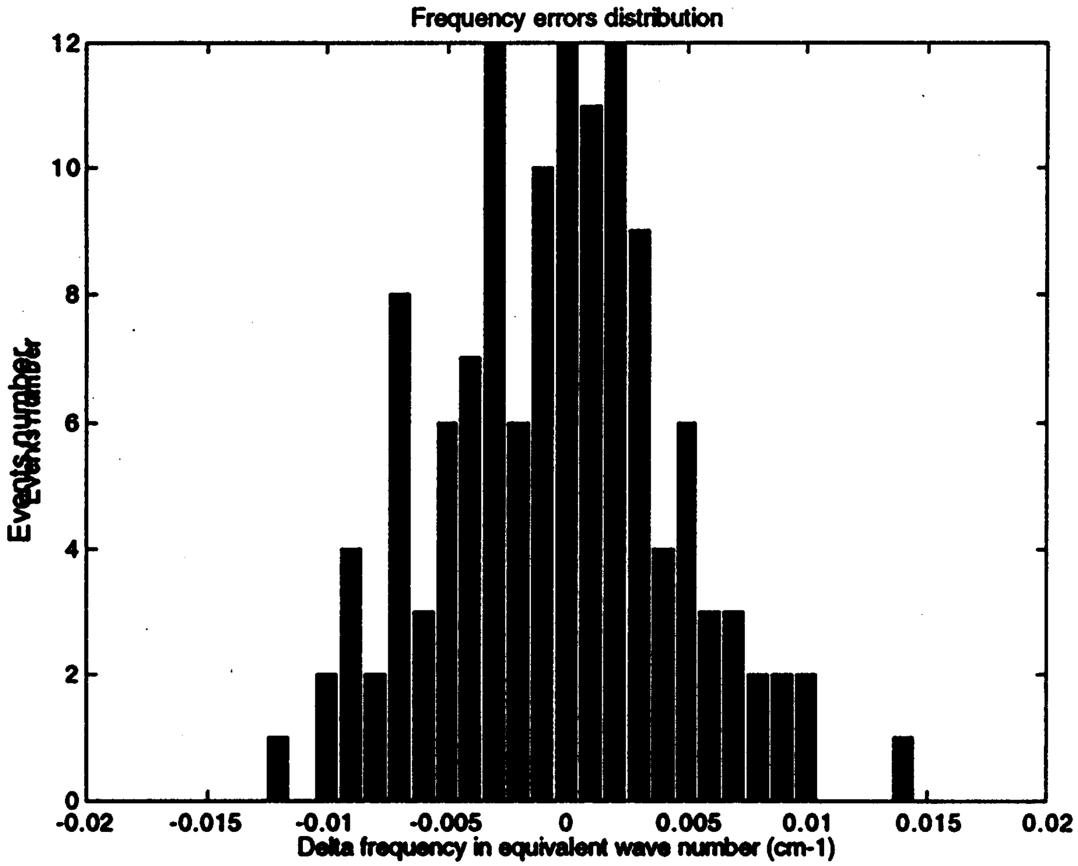
Signal Noise Ratio @ Velocity fluctuations: Std = 0.5%

Jitter noise sensitive edge

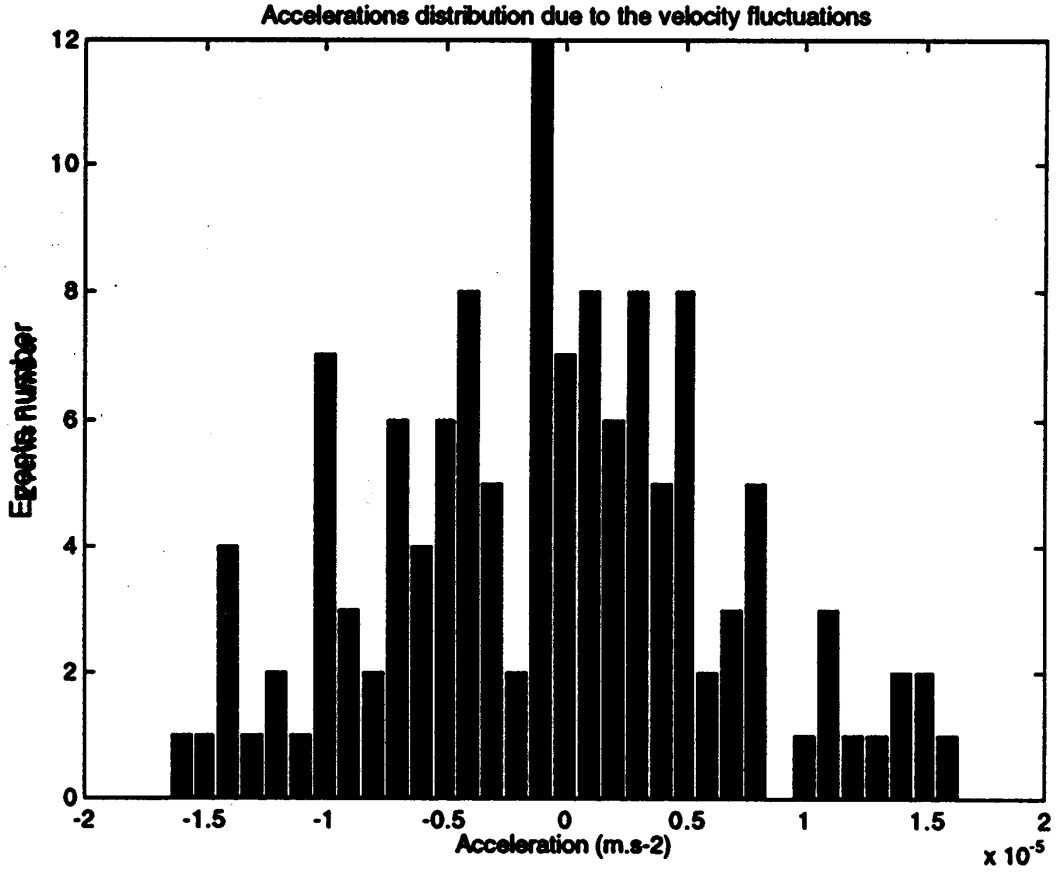
Velocity fluctuations sensitive zone

CONCLUSION: The SNR is better than the 0,5 μm jitter noise case

FREQUENCY ERRORS DISTRIBUTION


Frequency errors distribution

ACCELERATIONS DISTRIBUTION



Accelerations distribution due to the velocity fluctuations

Possibles substitutions to LVDT sampling system

LVDT----> Time sampling with velocity feedback loop + Fiducial position point ---->

With 4 x opd folding 1.2 µm opd seem maximum accuracy we can obtair

TWO SUBSTITUTION SOLUTIONS ------> POSITION SAMPLING----> velocity feedback loop

→ MOIRE FRINGES HEIDENHAIN SYSTEM

Need IR LED working at 4K with maximum around 0.8 µm

→ REFERENCE INTERFEROMETER
Need IR Laser diode (s)
TWO POSSIBLE CANDIDATES
InGaAs 0.85 µm-->1.5 µm WORKS
PbSnTe or PbSTe around 5 µm works

		Band 200-300 μm		300 600 μm	
F.A.	photon noise (10^{-17} W/$\sqrt{Hz}$)	2.0	2.8	1.0	1.4
	total noise "	3.6	4.1	3.2	3.3
	$(S/N)_{R=10}$	1500	2600	600	1200
	σ_{jitter} max	50nm/25 nm	15 nm		
	compress. factor	40% 20%	12%		
F.H.	photon noise	7.0	10.0	3.5	5.0
	total noise	7.7	10.5	4.6	5.8
	(S/N) R = 10	8700	13000 ⊛	5200	8200
	σ_{jitter} max	8.6nm 4.3 nm	3 nm		
	Compress. factor	8% 4%	2.5%		

⊛ 15 bits!

Martin-Pupplet

if $MPD = \frac{OPD}{2}$

Mach-Zehnder

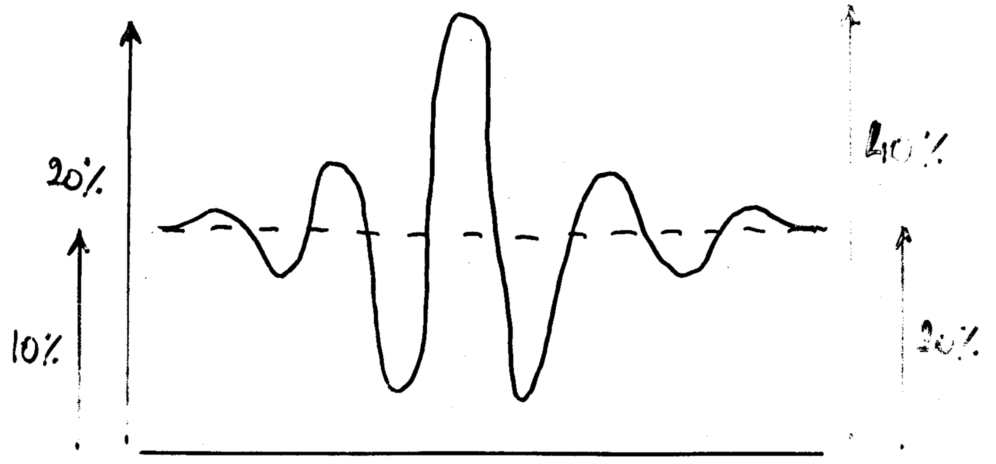
based on
$\sigma_{OPD} = 0.5$ μm
⇓
$(S/N) \sim 300$

JPB / 3.02.99 / QMW

SPIRE FTS

ASSUMPTIONS:

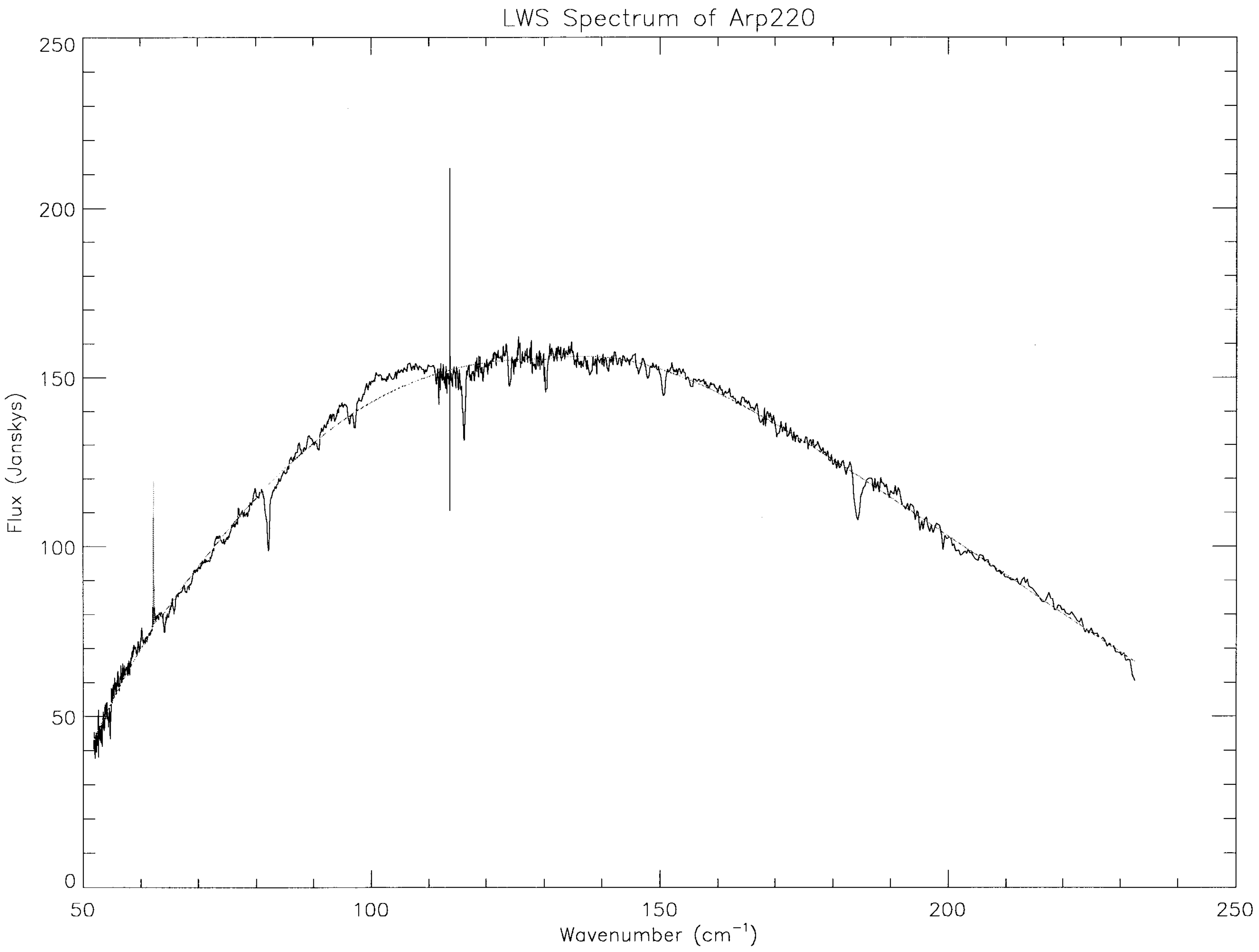
- TRANSMISSION
  Martin Pupplet.



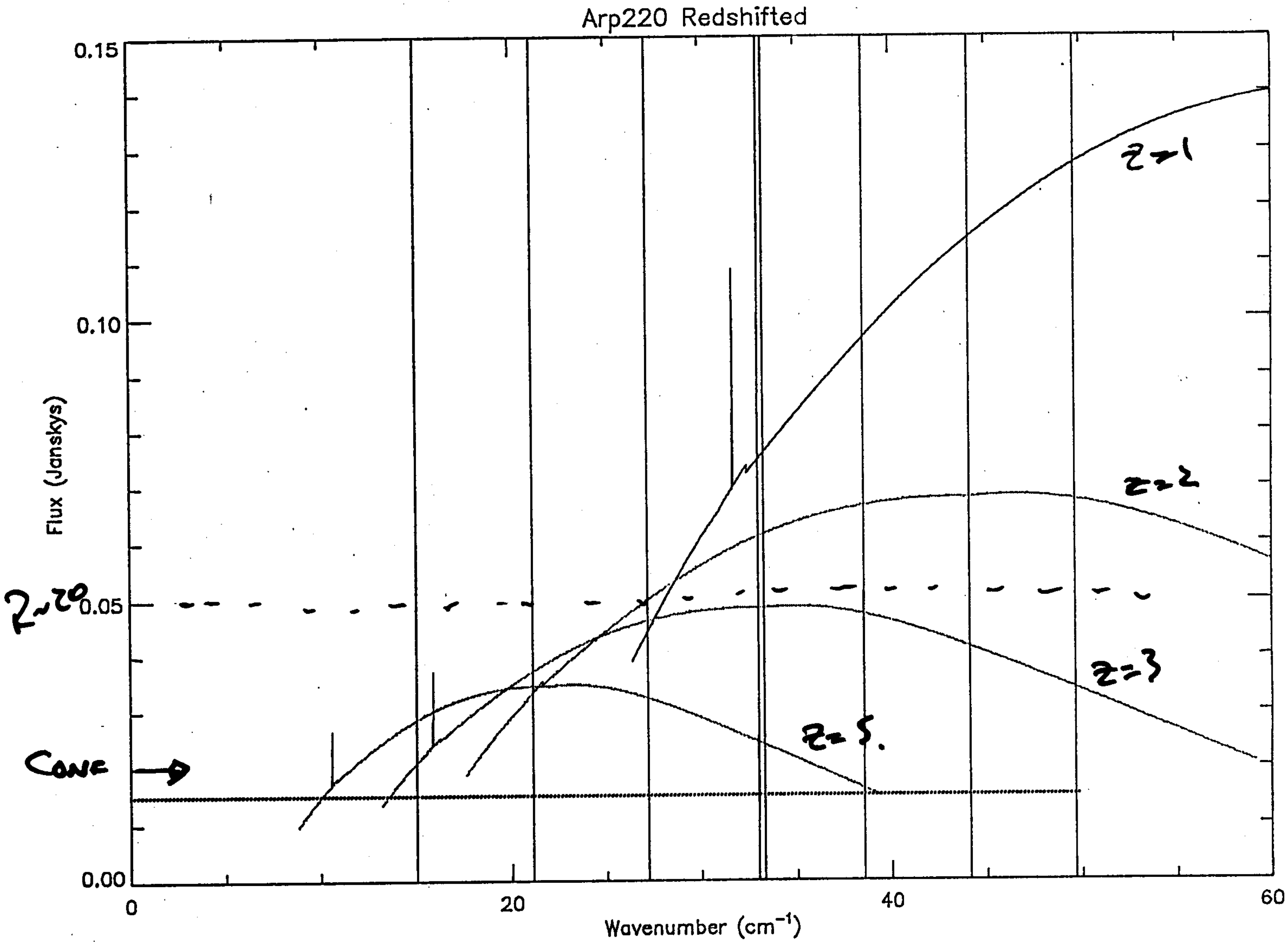
- BACKGROUND : $T = 80\,k$ $(\varepsilon = 4\%)$
  $T = 70\,k$ S/N ↘ 10%
  $T = 60\,k$ 20%

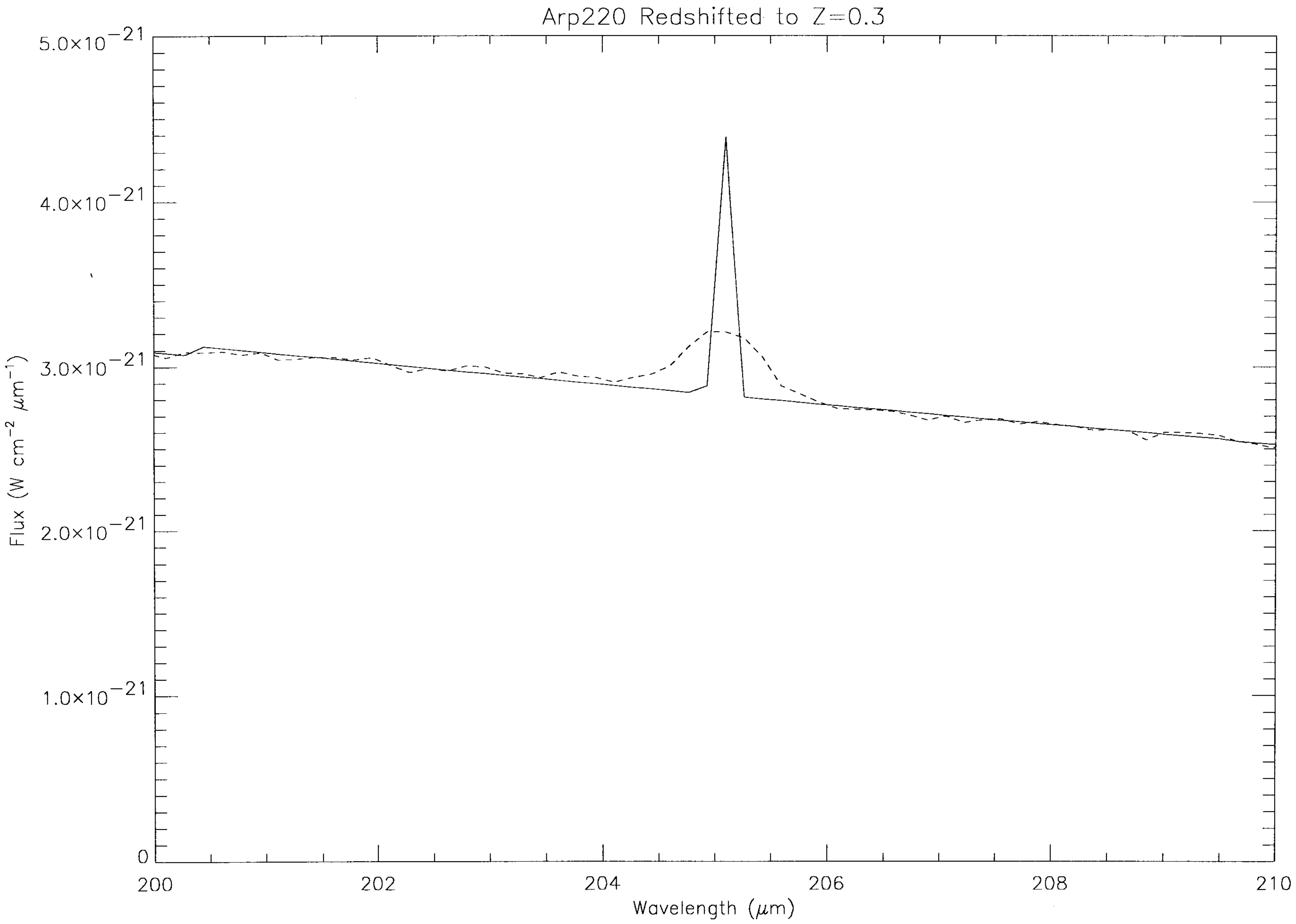
- BOLOMETERS : Filled Arrays ☐ pixel side $= \lambda_{min}/2D \sim 6''$
  Feed Horn array ○ pixel $\phi = 2\lambda_{min}/D \sim 24''$ $\Big\} \times 12.5$
  for both $NEP = 3 \times 10^{-17}$ $W/\sqrt{Hz}$

JPB / 3.02.99 / QMW



LWS Spectrum of Arp220


Arp220 Redshifted
Flux (Janskys)
0.15
0.10
0.05
0.00
Wavenumber (cm^{-1})
0
20
40
60
z=1
z=2
z=3
z=5.
Z~20
Cone


Arp220 Redshifted to Z=0.3
Flux (W cm^{-2} μm^{-1})
5.0×10^{-21}
4.0×10^{-21}
3.0×10^{-21}
2.0×10^{-21}
1.0×10^{-21}
0
200
202
204
206
208
210
Wavelength (μm)

Minimum detectable fluxes for intensity beam splitter FTS as a function of resolving power

Resolving Power	Minimum Detectable Flux (1-σ 1-hour)	
	50-33 cm^{-1}	33-15 cm^{-1}
3 ($\Delta\sigma$=13 cm^{-1})	1.4	1.3
6 ($\Delta\sigma$=6 cm^{-1})	3.1	2.8
10 ($\Delta\sigma$=4 cm^{-1})	4.6	4.3
100 ($\Delta\sigma$=0.4 cm^{-1})	46	43

Long wavelength band assumes uniform efficiency at all frequencies.

PHOTON NOISE LIMITED 1σ 1HOUR SENSITIVITY IN mJy

FTS Workplan:

2/3 Feb – Optics/FTS meeting

Decide on which type of FTS to progress with.

Outstanding issues preventing completion of detailed design:

- **FOV (can we decide this now?);** 2.6' x 2.6'
- **Detector Type;**
- **Telescope optical design;**
- **..........**

Issues that can be addressed "generically":

- **Translation into CAD system;** KD/RAL
- **Error budget;** KD
- **Alignment tolerance for each mirror;** KD
- **Diffraction analysis;** } RAL
- **Straylight analysis;** }
- **Mechanism type/requirements;** DP/GM
- **Position sensor type/requirements;** GM.
- **Operation of FTS** JM/LR.
- **.................**
- FEEDHORNS → } PARA
- NUMBER OF BANDS }
- CALIBRATION SOURCE. JPB (REQS) (CONSOL/BUS SPEC)
- DATA RATE. } LR/PAH
- ON-BOARD PROCESSING }

Next dates:

14 FEB VALENTINE'S DAY.

~~15 Feb Focal Plane sharing meeting at ESTEC~~

4/5 March System Team Meeting

CAD MODEL
DATA RATE/OBS
POSITION SENSOR.

~8 March "Opto-mechanical conceptual design progress review"

15 March ESA Technical Meeting

DATA RATE

Mid/Late-April "Opto-mechanical conceptual design progress review"

MECHANISM - FIRST ORDER SOLUTION(S).
OPTICAL LAYOUT FINALISED.

July ESA Technical Meeting to close s/c interfaces