Some surface measurement work in XAO and high precision surface challenges on QTT

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  - Photogrammetry
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  - Qi Tai 110m telescope
- Conclusion

Nanshan 25m telescope

- Upgrade plan
  - Mar. – Oct. , 2014, Antenna structure, reflector, servo control…
  - May – Oct. , 2015, Antenna rail


July 28, 2014

XAO


May 27, 2015

Photogrammetry at Nanshan 25m

- Aug. 9 –Aug. 31 , 2014
- Chenway Technology Inc. & CETC 39 Institute
- Measurement system
  - Dedicated camera, retro reflector, reference meter, directional gauge, image processing software


ZOOMLION
QY80V

Photogrammetry at Nanshan 25m

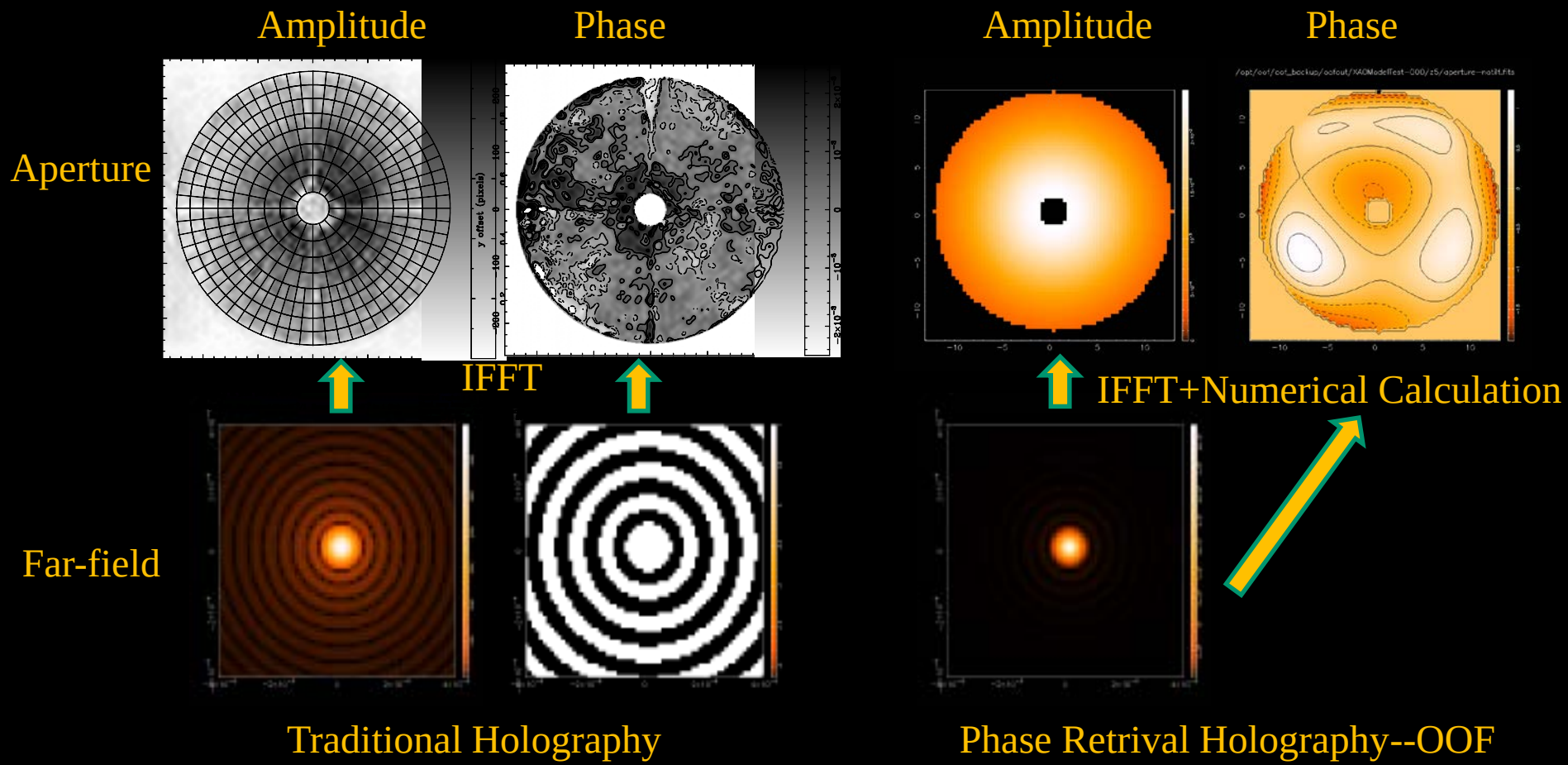
- 6 measurement and 5 adjustment before feed cabin installation
  - RMS： 5.504-> 8-> 0.847->0.451->0.271->0.177(mm)
- 2 measurement and 1 adjustment after feed cabin installation
  - RMS： 0.202 ->0.173(mm)
- RMS under different Elevation

EL	RMS (mm
90°	0.536
38°	0.173
20°	0.489
6°	0.561

The surface deformation is a little larger due to gravitational effect!

Microwave Holography at Nanshan 25m Telescope

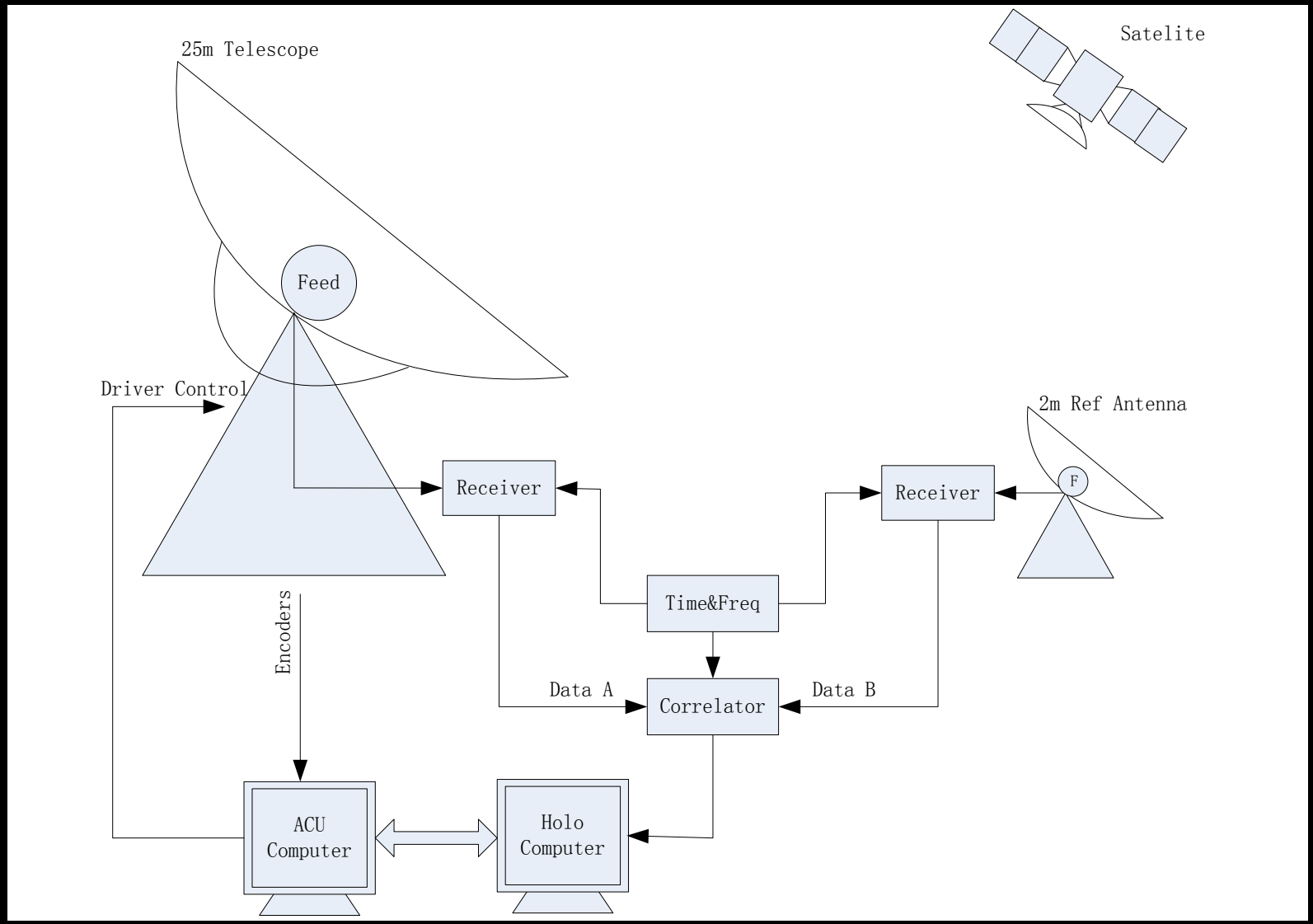
- With Phase Holography(Traditional)
- Phase Retrival Holography(Out Of Focus)



The Difference between Traditional Holography and OOF

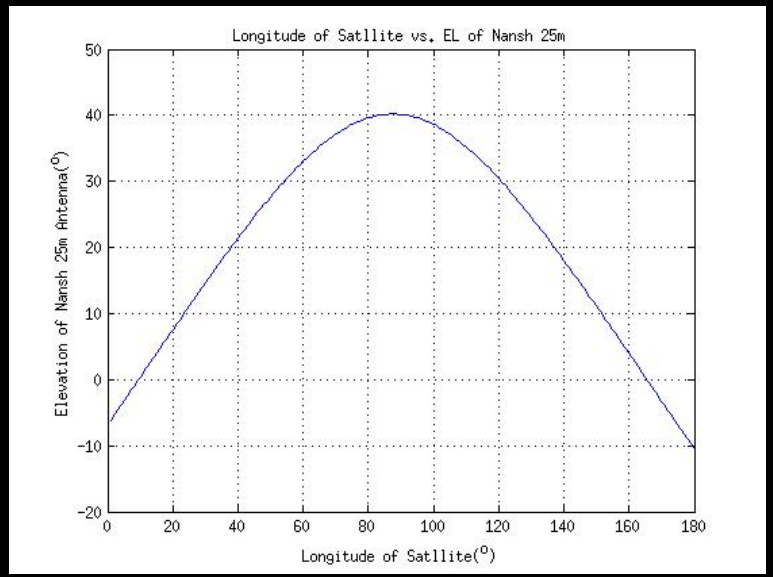
	Traditional Holography	OOF
Measured data	Amplitude + Phase	Amplitude
Measurement error	~100μm,10μm(ALMA)	λ/100 (SNR:200:1) For 1.3cm: ~130μm
Resolution	D/N, High, Single panel	Low, for large scale deformation
Time consumption	~2hours	<20mins
Source	Geostationary satellites	Radio sources
Observed elevation	Fixed	Full range
Observed Band	Ku, Ka…	K,Ka,Q…arbitrarily
Software	Simple	Complex
Hardware	Reference antenna and receiver + Correlator	Removeable sub-reflector

Traditional Holography System Design



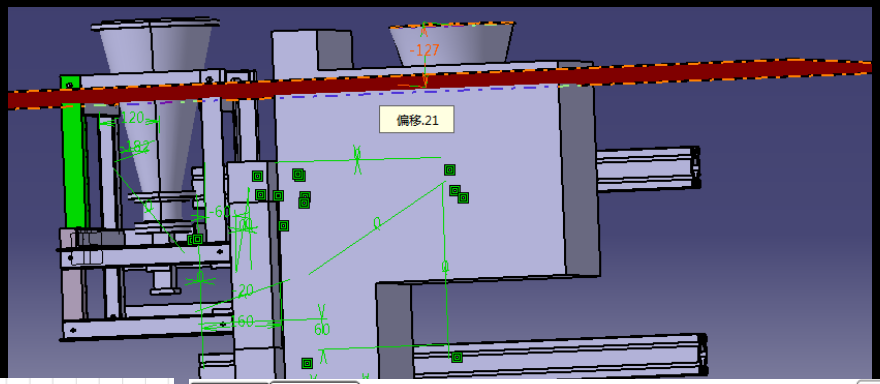
Satellite Select

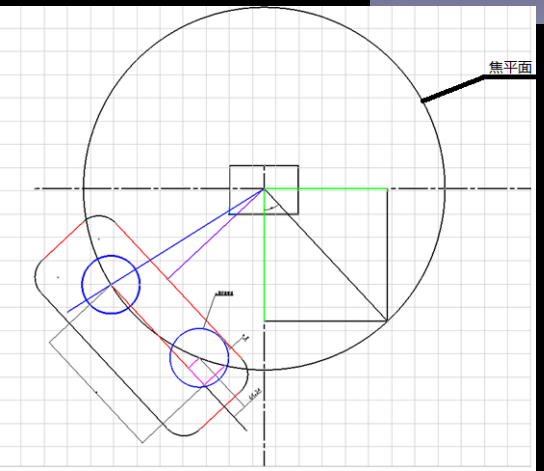
Satellite Name	Orbital Position/ ° E	Ku band beacon/MHz	Az、El of Nanshan 25m	EIRP /dBW
		Horizontal		
ChinaSat 10#	110.5	12745	148.2， 35	46
ChinaStar-1	87.5	12749.5	180， 40.2	45
AsiaSat-3	105.5	12749	154.6， 37	44
AsiaPasific-2R	76.5	12749	195.8， 39	45

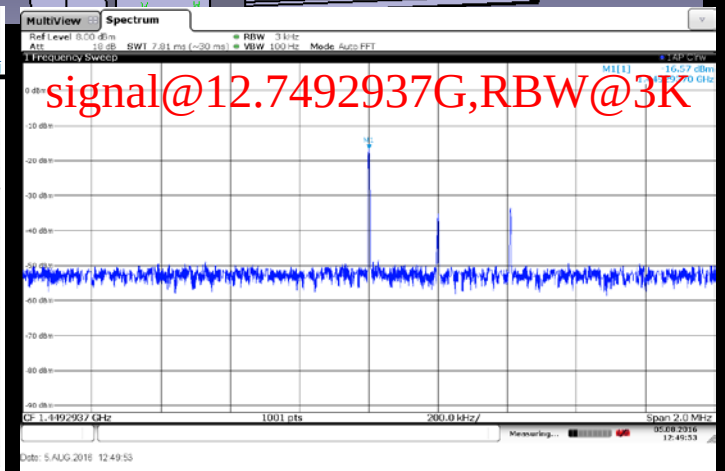


Feed Installation

- Using back shelf of K-band receiver, can move along three dimension, very easy to installation, adjust and remove

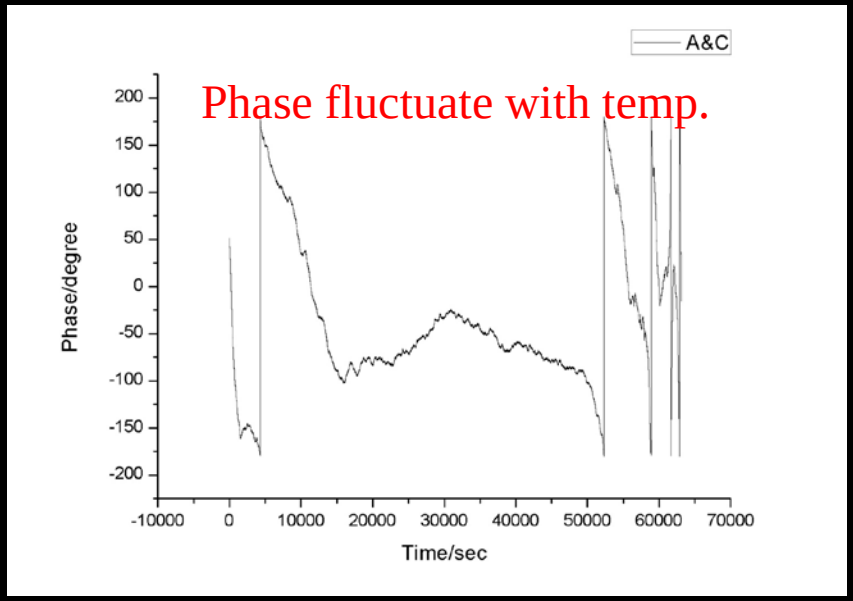


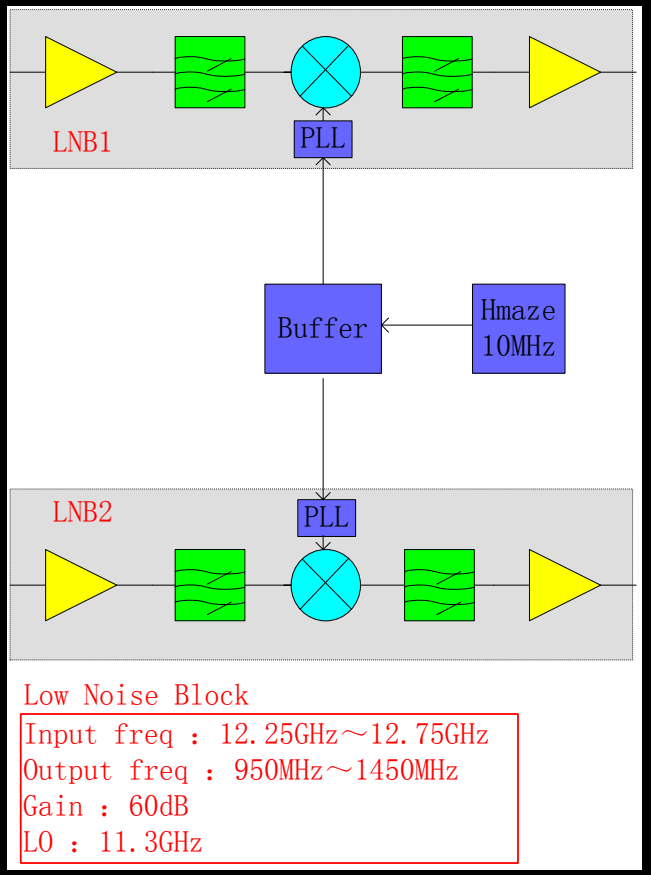




Receiver

- First plan: Norsat LNB,1007XHBN
  - pro's: Internal 11.3GHz LO, just need a ext. 10M ref.
  - con's: bad phase stability



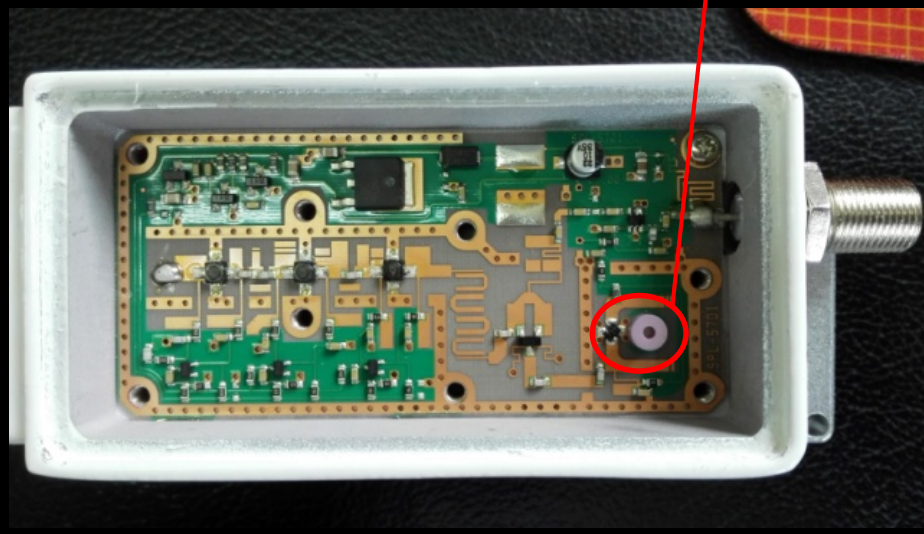


Low Noise Block

Input freq : 12.25GHz～12.75GHz
Output freq : 950MHz～1450MHz
Gain : 60dB
LO : 11.3GHz

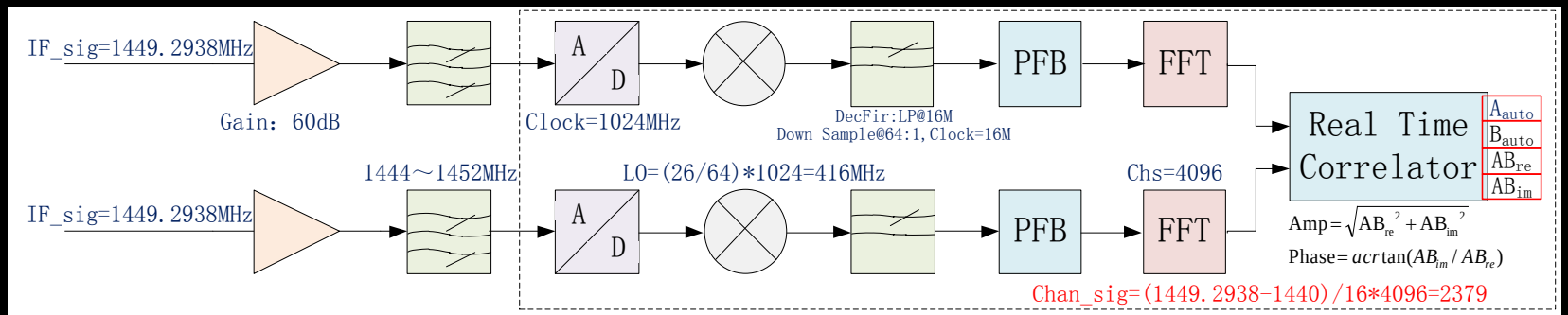
Receiver

- Revised plan
  - Ext. 11.3GHz PDRO
    - KRATOS CTI
  - Atron LNB
  - Very good phase stability
    - 2.5h test, STDEVP about 1.68deg



Correlator

- ROACH2 board + CASPER library
- Dual channel, 2G, 8bit sampling
  - band pass sampling—needn't base band converter
  - digital mixer and filter—bandwidth adjustable
  - high precision, good stability

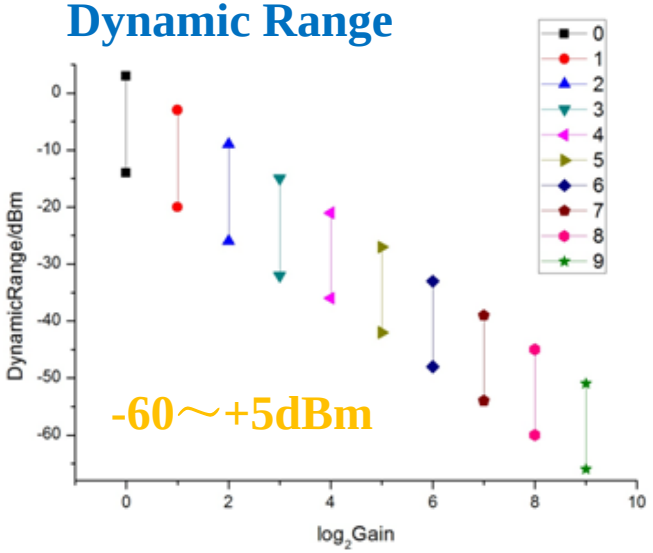


ROACH2 Correlator Performance

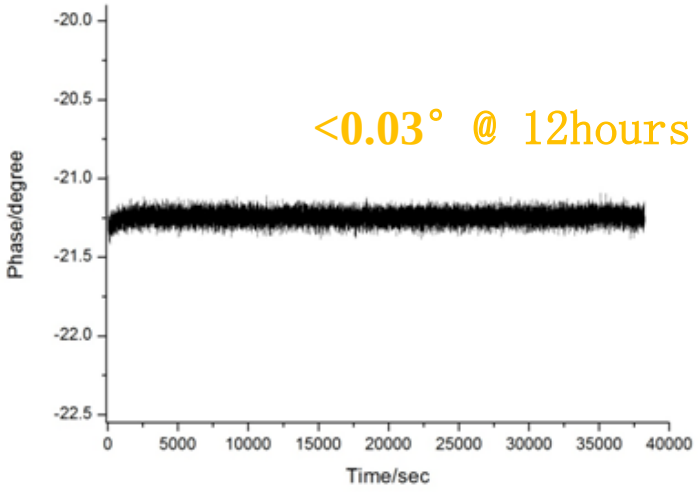
Dynamic range : -54dBm～-15dBm
Band Width : 16MHz
A/D Sampling : 1024MHz
Points of FFT : 4096
Sampling bits : 8 bit
Integration time : 1 sec
Spectrum resolution : 3.9kHz
Nyquist Zone:3(1024～1536MHz)
Bandpass BW: 1440～1456MHz

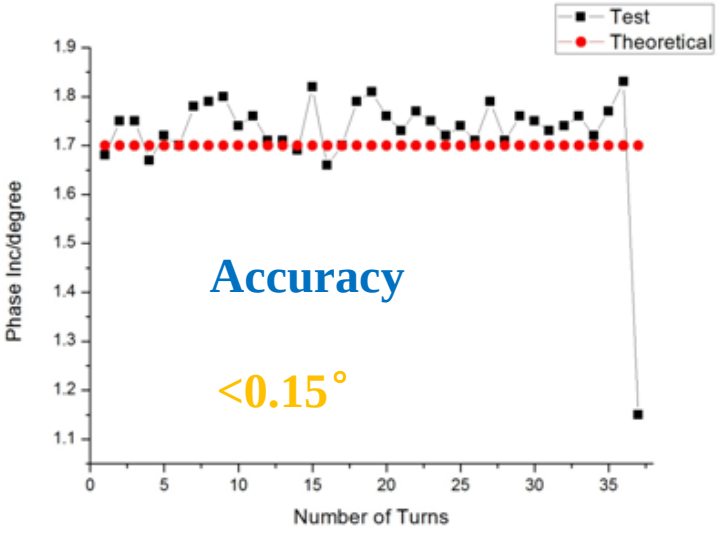
Correlator Test Result

Dynamic Range

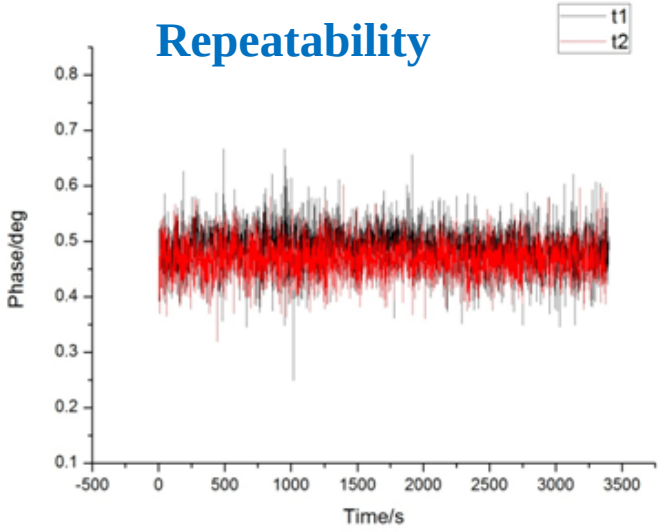


Stability



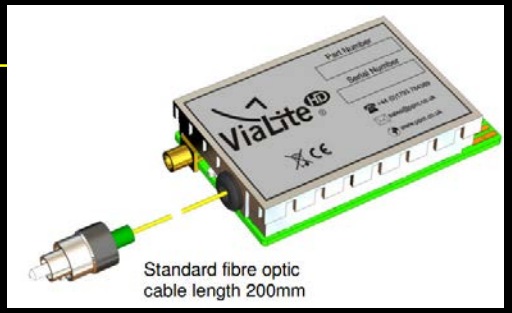


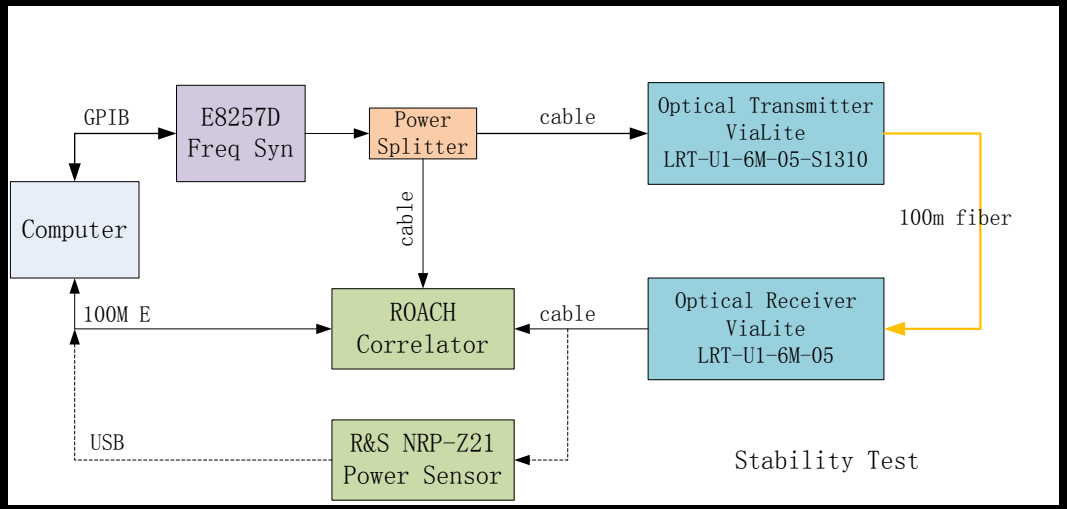
Repeatability

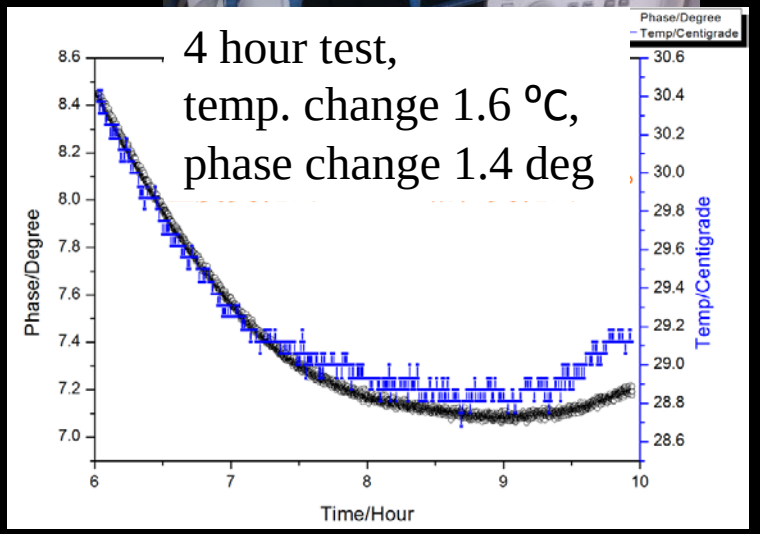


Transmission Link

- First plan: fiber optic transmission
  - pro's: good phase stability
  - con's: bad phase stability due to optical receiver and transmitter temp. variation

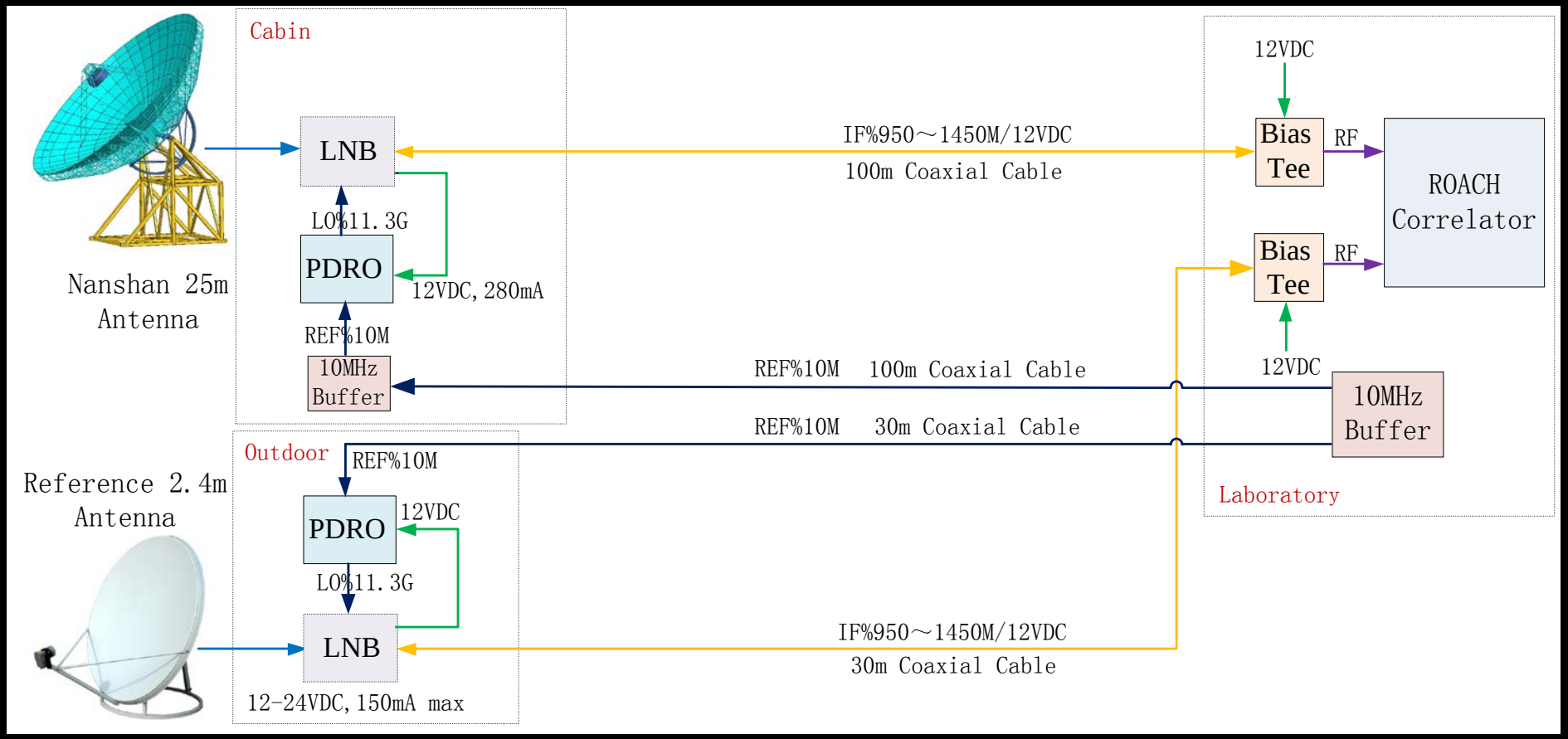




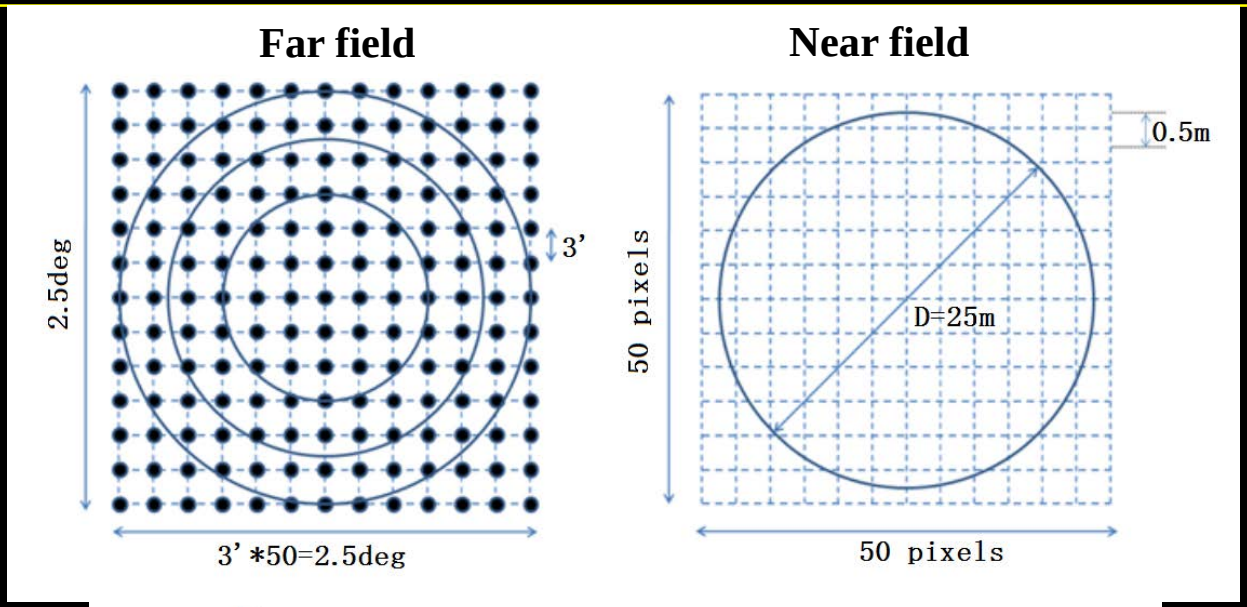


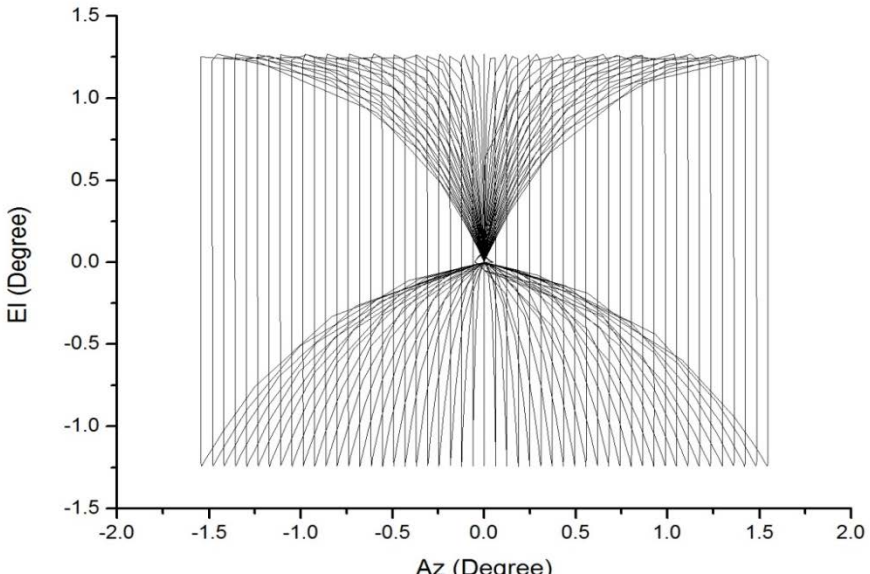
Transmission Link

- Currently used: coaxial cable

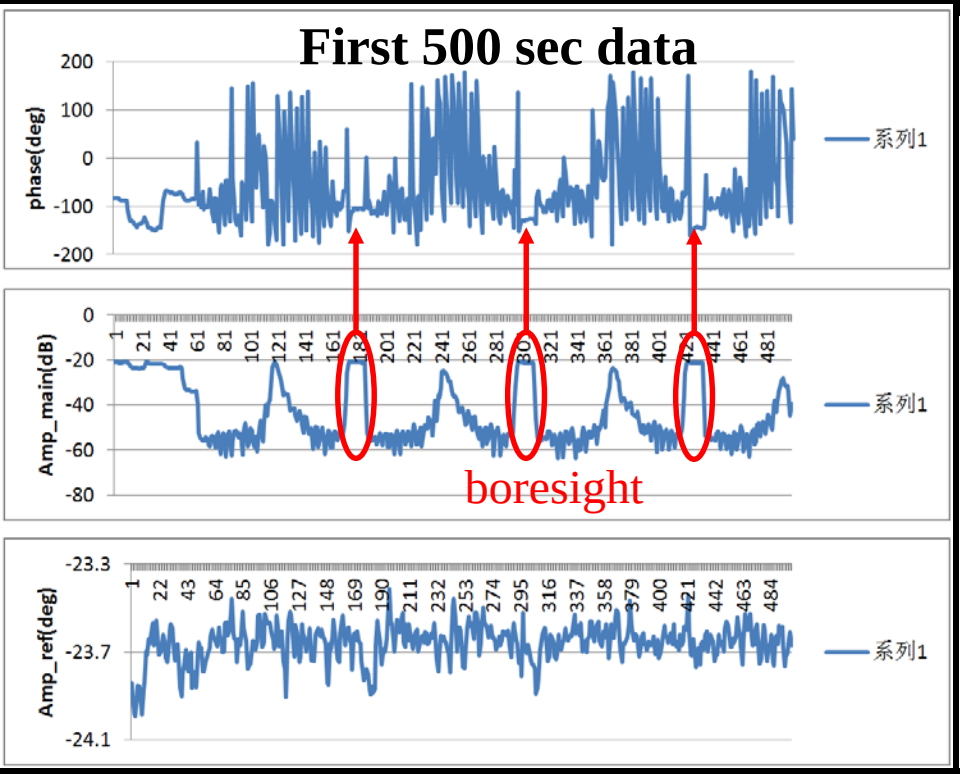


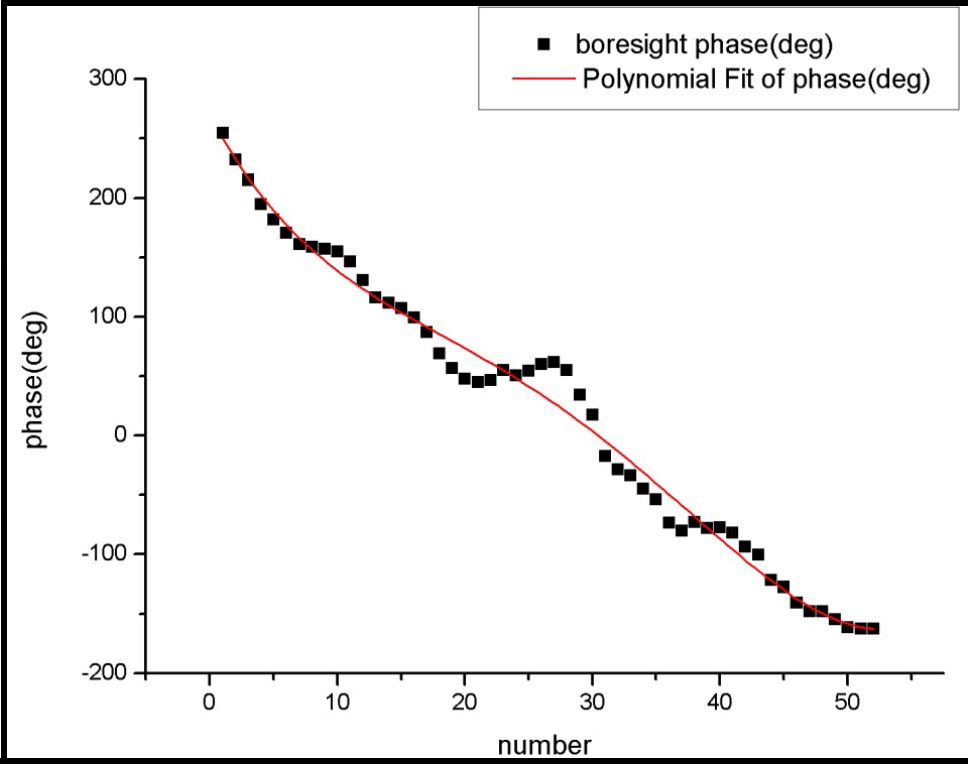
Scan control





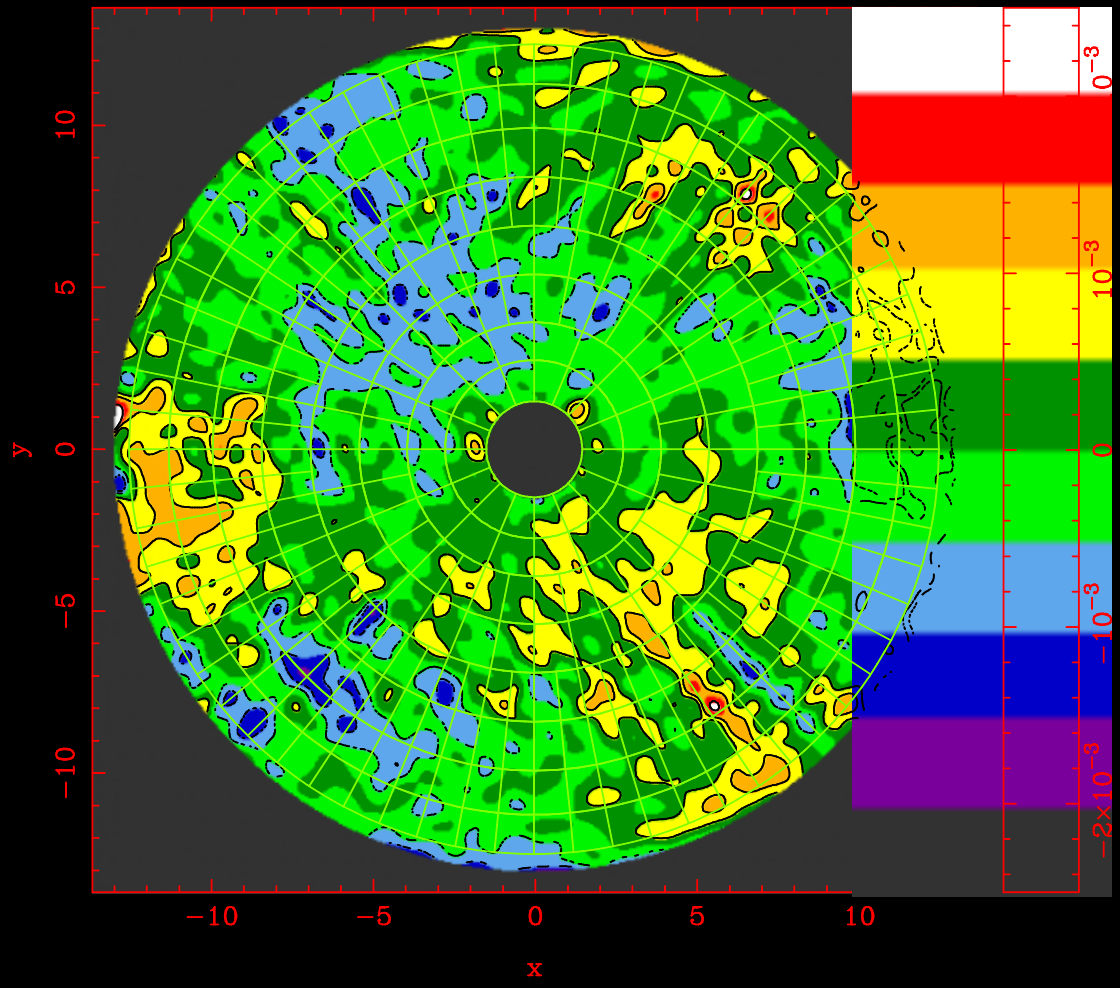
Holo Test result

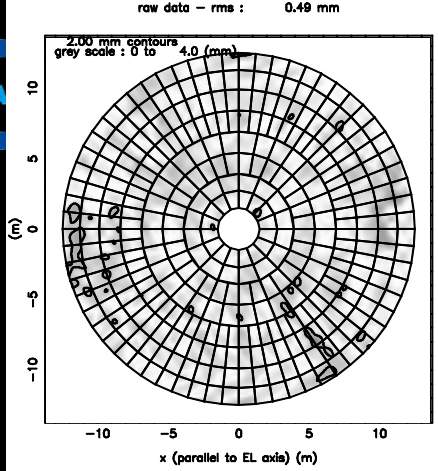


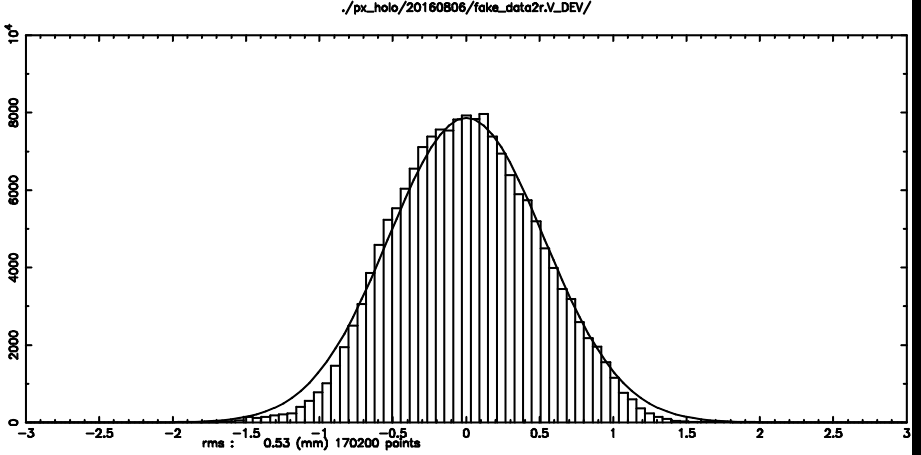


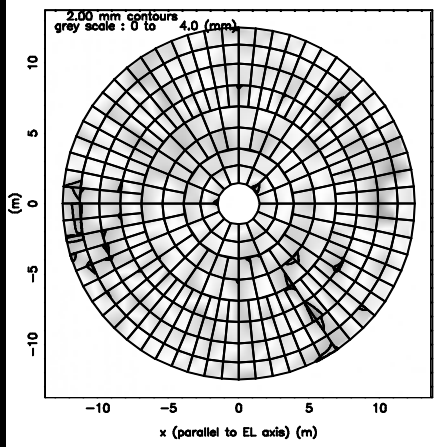
Holo Test result

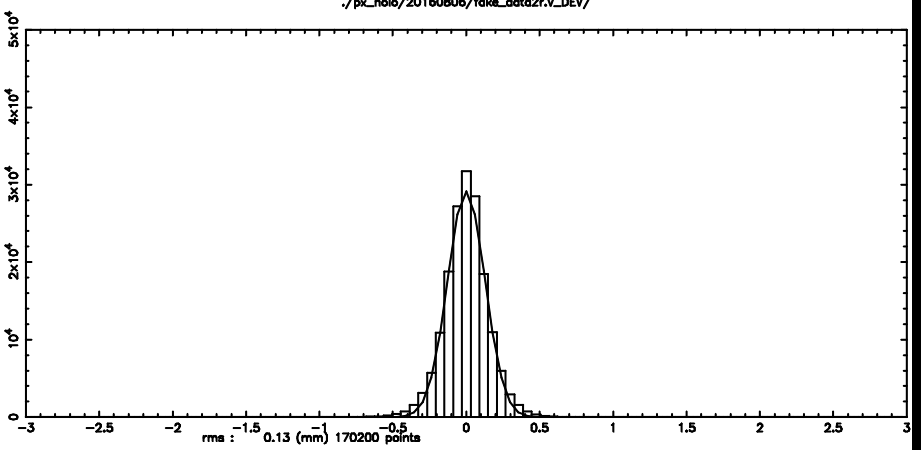
- Surface error distribution

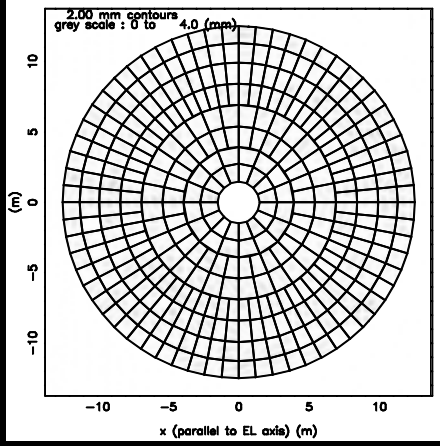












Before adj(RMS)：0.49mm

After adj(RMS)：0.15mm

OOF Technique

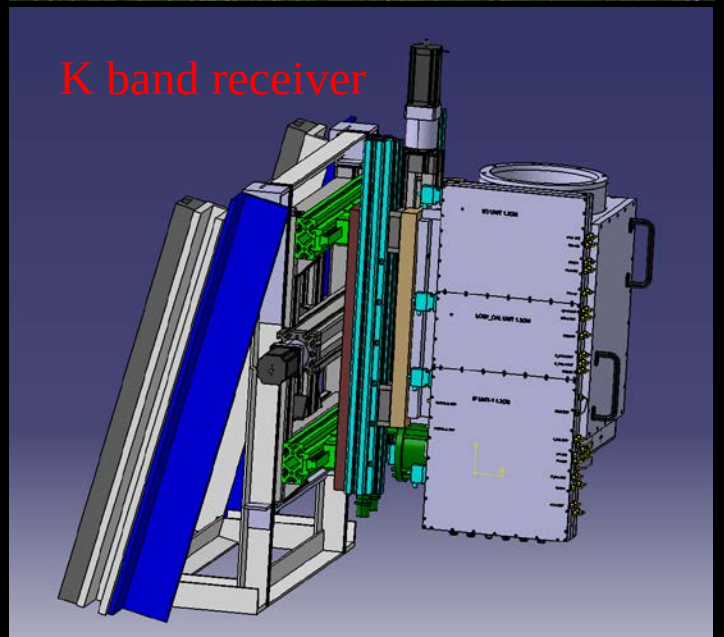
- 2003,Bojan Nikolic, University of Cambridge, U.K.
- Phase retrieval , measure power only of far-field beam pattern on bright astronomical calibrator
- Make three beam maps, one in focus, two in defocus
  - Parametrisation of surface errors -- Zernike polynomials
  - Solver algorithm -- Levenberg-Marquardt maximum-likelihood
- Adjust coefficients to minimize difference between model and actual beam maps
  - Correction for residual gravitational deformations , and ”real-time” thermal deformations
- For closure active surface control system

Advantages

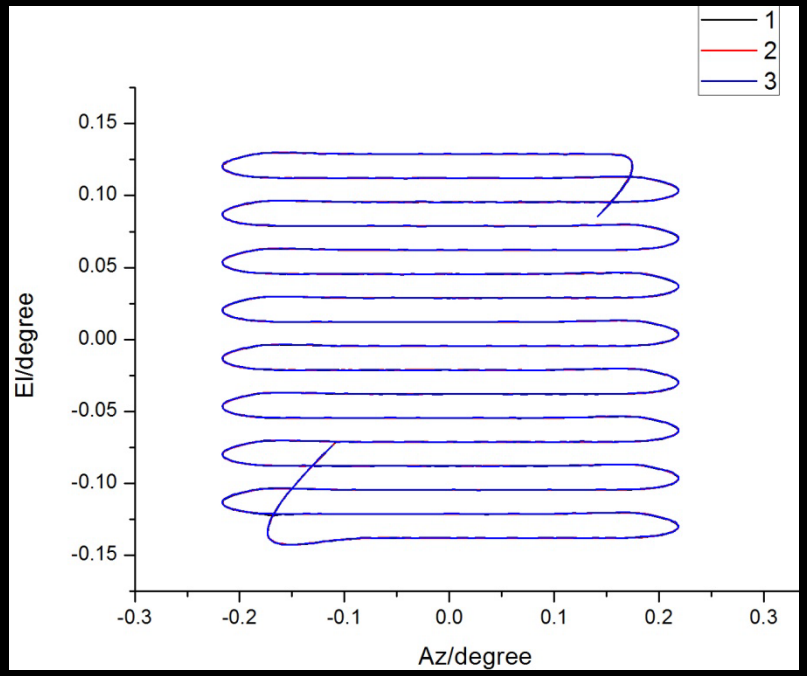
- Measure the complete optical aberrations
  - Surface errors + mis-collimation + receiver optics...
- Fast
  - Several minutes
  - “Near real-time” closure active surface control system
  - Faster when using multi-beam or focal-plane array
- As a function of elevation, time of day, etc
  - Measure the effect of gravity
  - Measure the thermal deformation
- Without extra equipment
  - Makes it easy to interleave with science observations
  - (Zero materials cost)

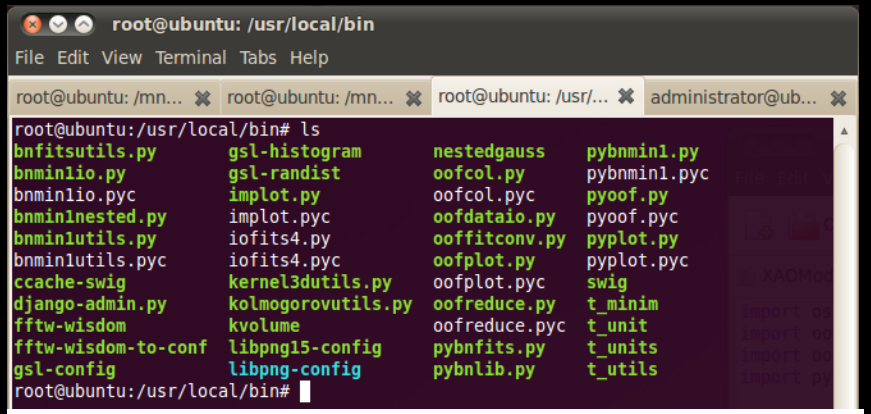
Out Of Focus Holography at Nanshan 25m

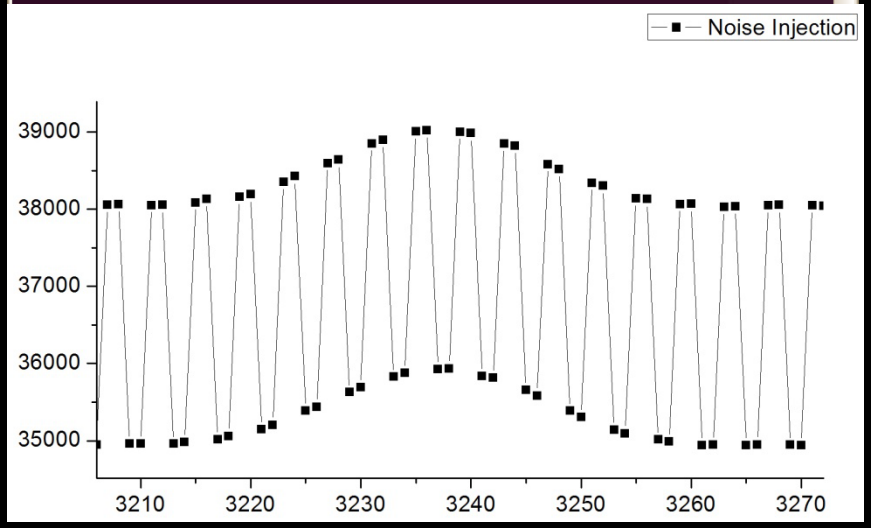
- Feb., 2013, Old 25m system, K band
- BW: 500MHz
- Beam: 2.18’
- Defoucus: ±70mm
- Moving pattern: moving back shelf vertically
- Sources: 3C84
- Tsys: 40K
- SNR: 100:1
- Az Length: 30’
- El Length: 1’*16=16’
- Scanning speed: 3’/s at Az
  (Max Az Speed: 60’/s, Max El Speed: 30’/s)
- Integration Time: 32ms/64ms
- Sampling Time: 32ms/64ms



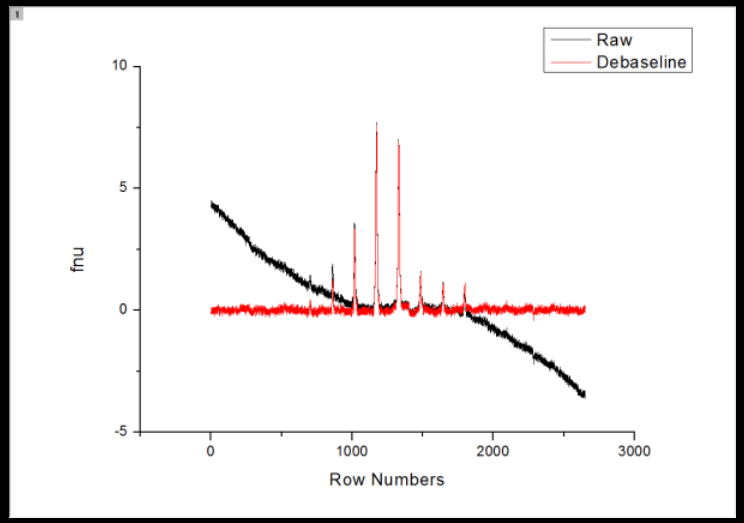
- Antenna control software(set scan mode and trajectory)
- Data acquisition software
- Noise injection
- OOF software installation(from Bojan)

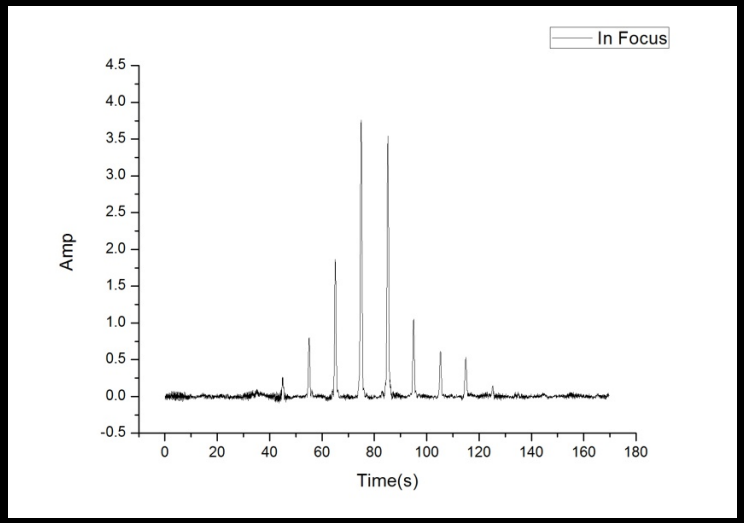


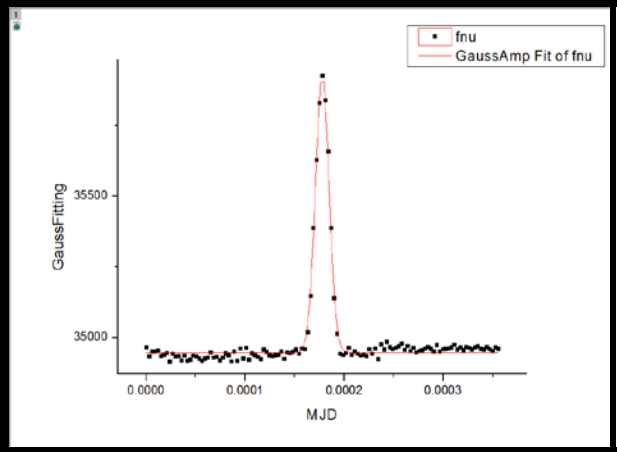


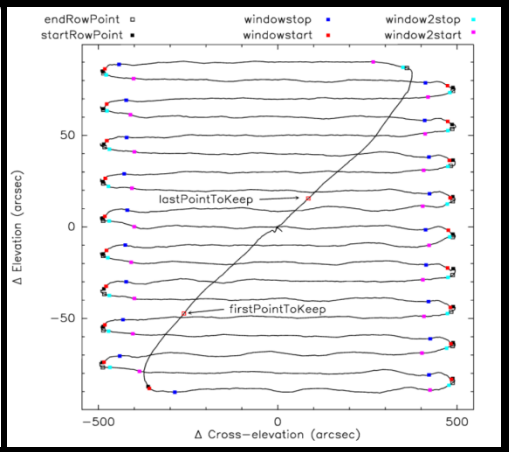


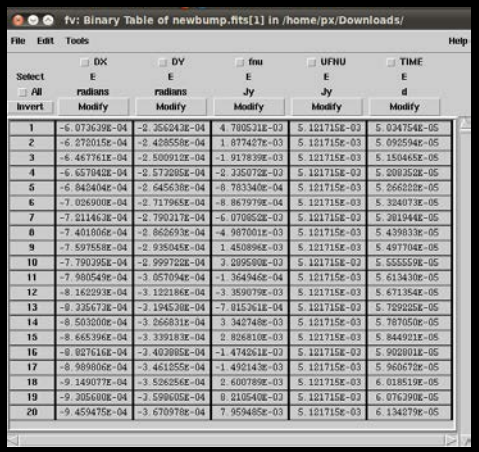
- Data pre-processing
- FITS file data
- Debaseline











OOF Maps of Nanshan 25m

Zernike polynomials

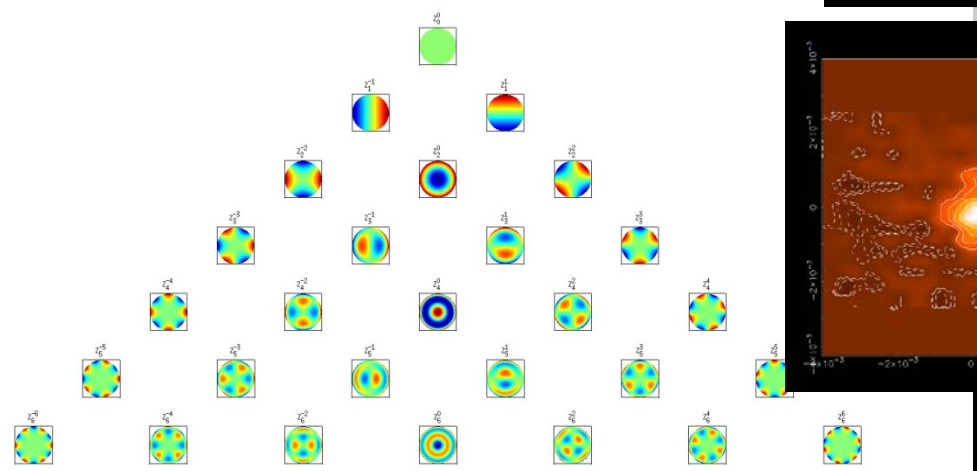
Aperture phase and amplitude distribution

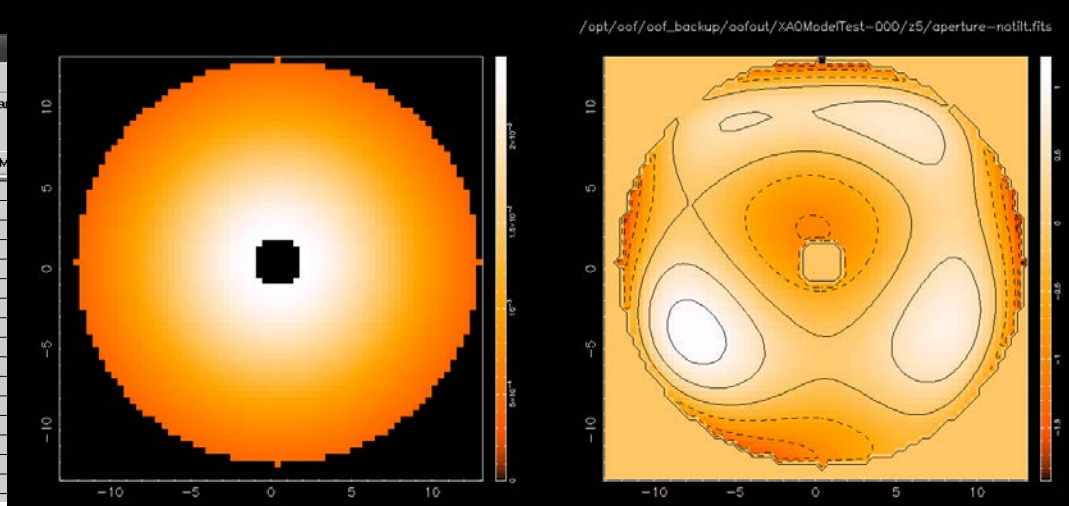
fv: Binary Table of fitpars.fits[1] in /home/px/Downloads/oofout/s114-l-db-001/z5/

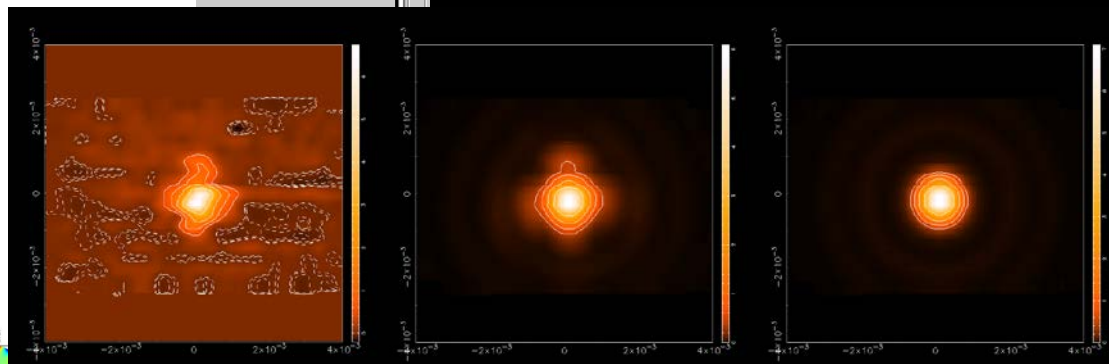
File Edit Tools

Select All Invert

	ParName 30A	ParValue E	DoFit I	
		Modify	Modify	Modify	
1	amp	9.132390E-04	1	Illumination amplitude
2	sigma	3.000000E-01	0	Illumination taper
3	x0	0.000000E+00	0	Illumination offset in horizontal
4	y0	0.000000E+00	0	Illumination offset in vertical
5	z0	0.000000E+00	0	coeff. of Zernike n=0 , l=0
6	z1	-1.226602E-01	1	coeff. of Zernike n=1 , l=-1
7	z2	-6.266849E+00	1	coeff. of Zernike n=1 , l=1
8	z3	1.081935E-01	1	coeff. of Zernike n=2 , l=-2
9	z4	-9.170491E-02	1	coeff. of Zernike n=2 , l=0
10	z5	1.864050E-01	1	coeff. of Zernike n=2 , l=2
11	z6	-1.951748E-02	1	coeff. of Zernike n=3 , l=-3
12	z7	-1.095982E-01	1	coeff. of Zernike n=3 , l=-1
13	z8	-6.867645E-02	1	coeff. of Zernike n=3 , l=1
14	z9	3.466250E-02	1	coeff. of Zernike n=3 , l=3
15	z10	-6.291842E-02	1	coeff. of Zernike n=4 , l=-4
16	z11	-1.557280E-02	1	coeff. of Zernike n=4 , l=-2



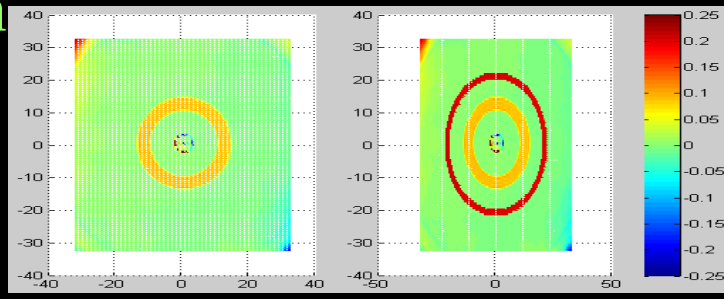


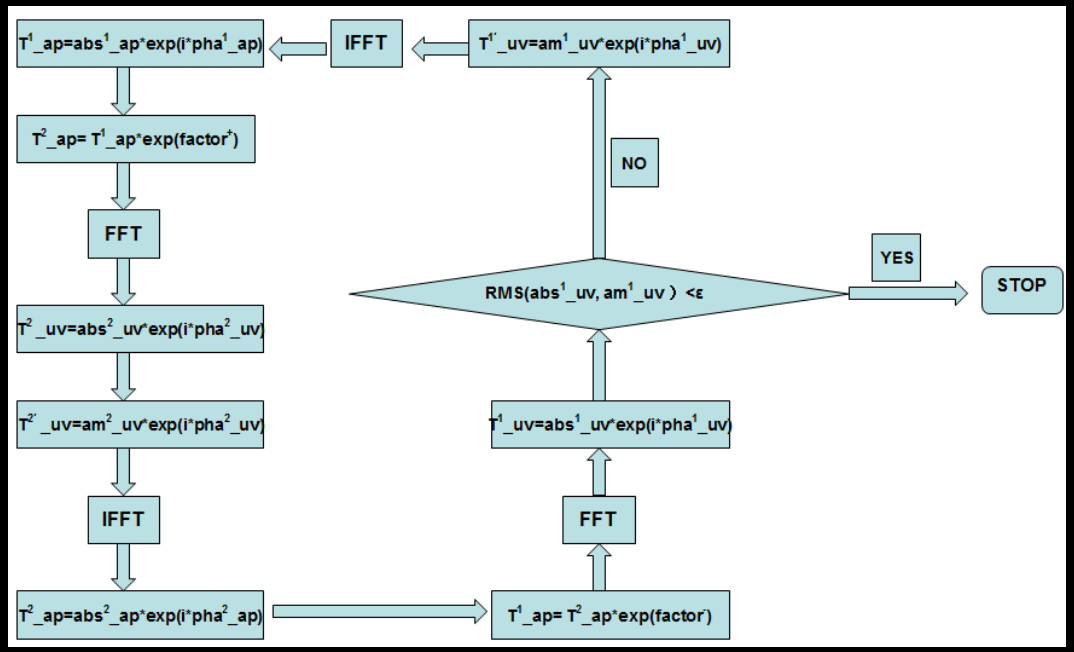


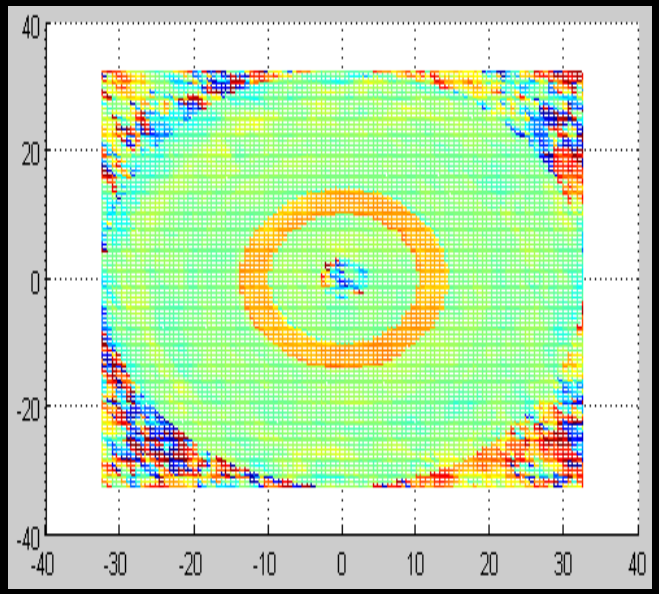
Beam maps

Other methods research

- Active surface de-focus algorithm
  - A sort of phase retrieval algorithm
  - move main surface for de-focus
  - Add a ring error in main surface

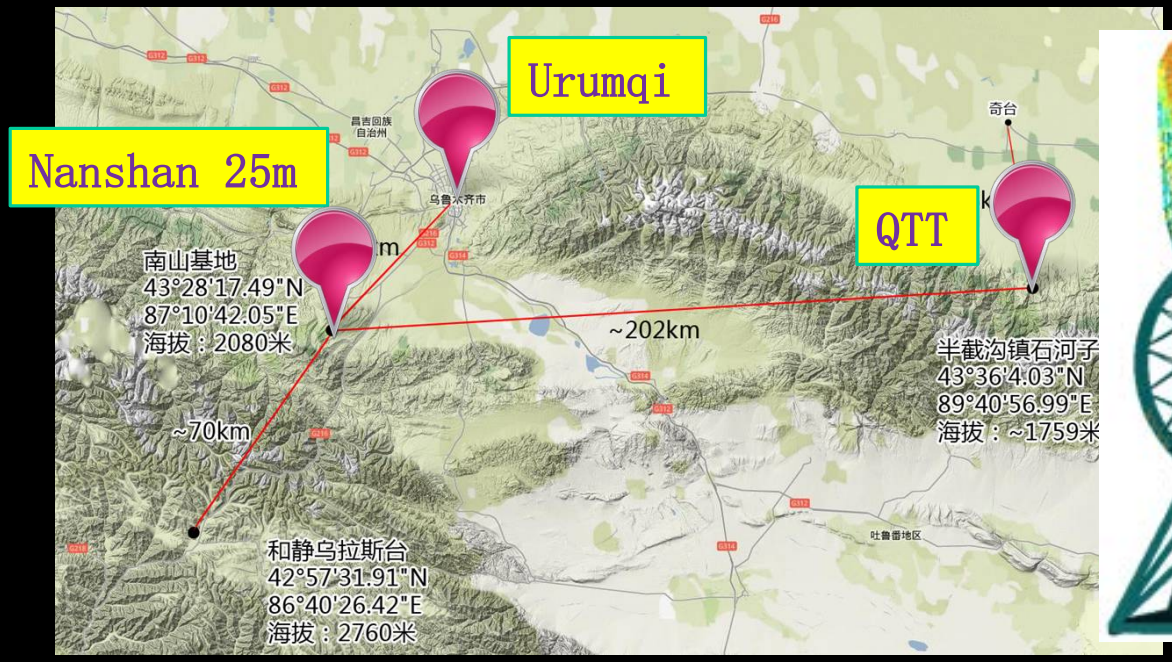


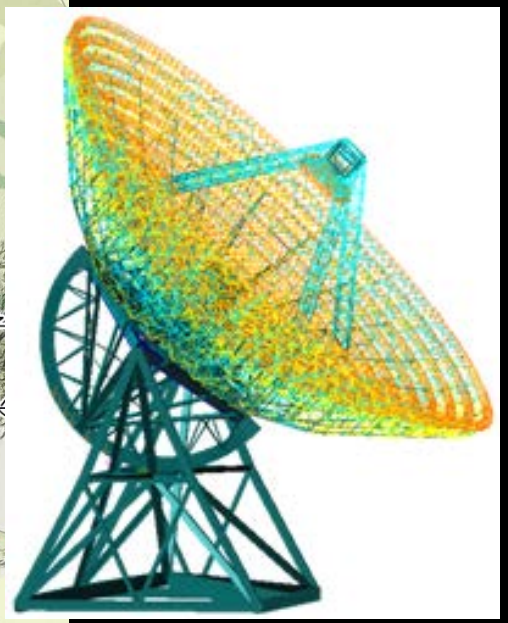




Qi Tai radio Telescope(QTT)

- 260km from Urumqi, 202km baseline from Nanshan
- 110m , fully moveable, 150M~117GHz,Active reflector
- Surface accuracy RMS： <0.2mm
- Blind pointing error： <5”





Key Point for QTT High Precision Surface

- Design
  - Decrease geometric approximate error, homology, partitioning, gravity and thermal effect simulation
- Machining
  - Promote machinng precision, technology and machine, factory testing
- Installation
  - 3 step, theodolite coarse adjust → photogrammetry tiny adjust → holography fine adjustment
- Compensation
  - closed loop control active surface system, FEM model, real time surface measurement, active sub-reflector…

Conclusion

- Some surface measurement methods were researched, experimented in XAO for QTT pre-research
- System is easy to build, but hard to get high measurement precision
- Real time surface measurement challenge and chance
  - Very fast, Any elevation
  - Low resolution, for large scale deformation
  - Feedback, for closed loop active surface compensation
  - Collaboration on the new methods research

Thank you !