Development of A THz FTS for Site Testing at Dome A

Sheng-Cai Shi[1]

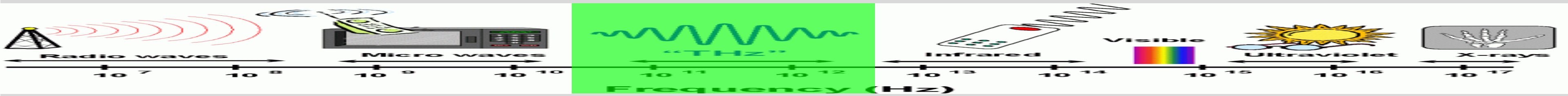
S. Paine[2], Q.J. Yao[1], X.X. Li[1], X.G. Zhang[1], Z.H. Lin[1], H. Matsuo[3], J. Yang[1], Q.Z. Zhang[2]

A collaboration between PMO[1] and CfA[2]

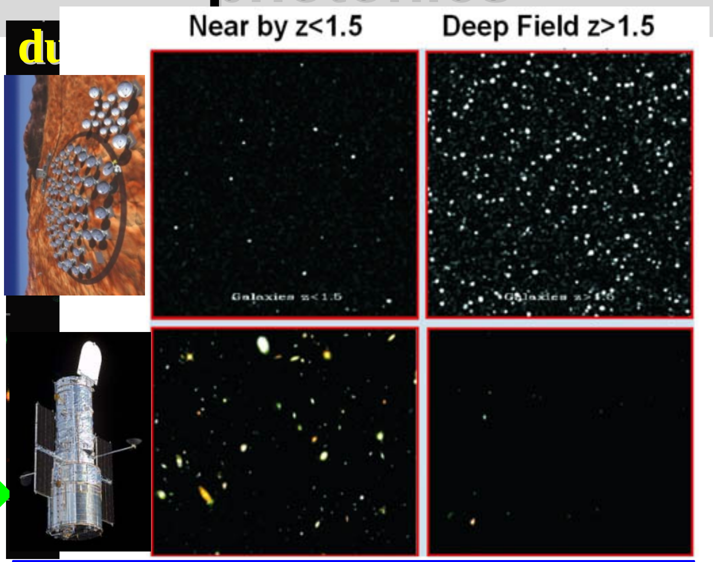
OUTLINE

- **Introduction**
- **Design of the System**
- **Sensitivity & Calibration**
- **Control/DAQ System & Software**
- **Timeline for FTS Development**
- **Conclusion**

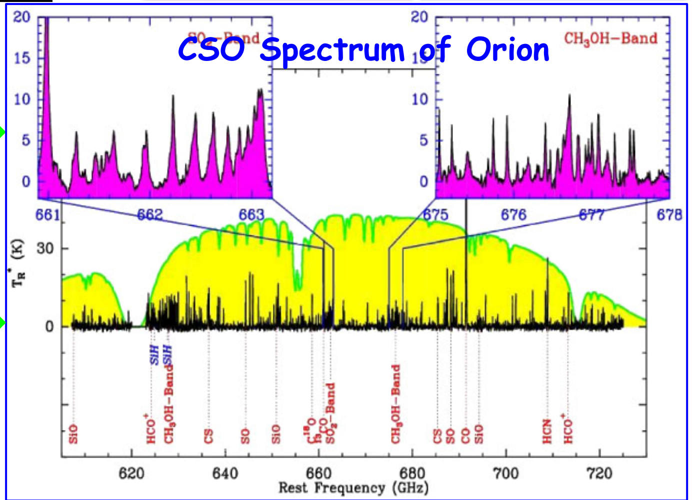
Why do THz Astronomy?



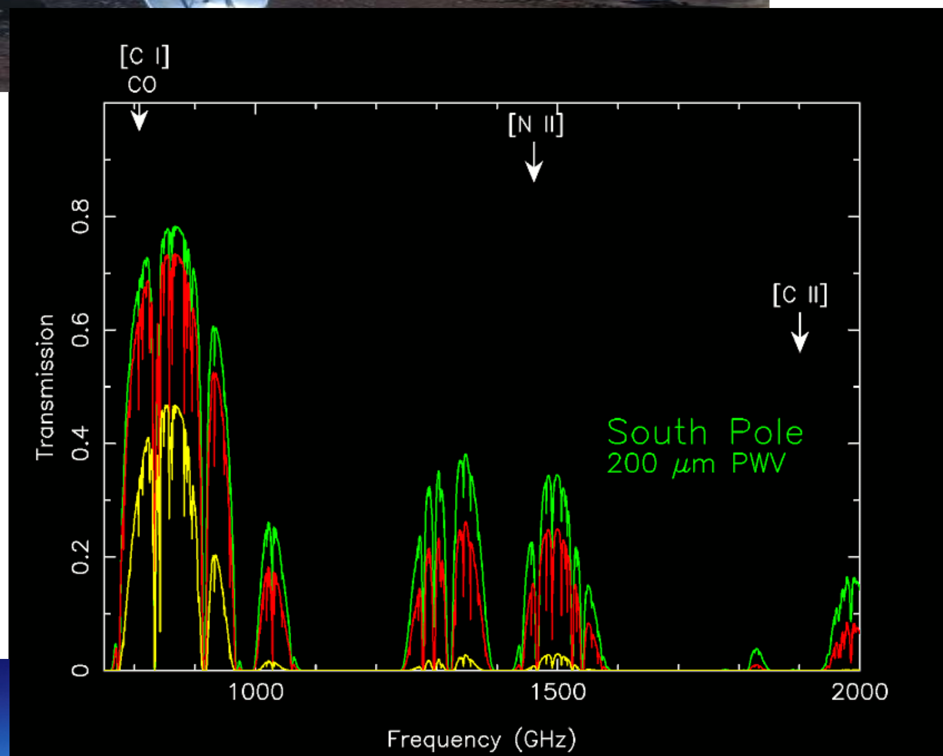
electronics ← Size~λ | $h\nu \sim k_B T$ → **photonics**



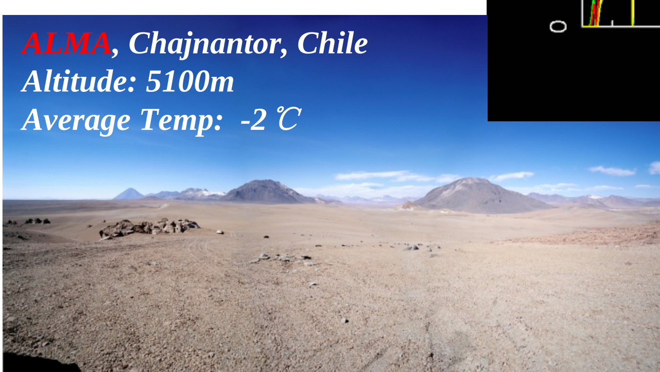
- ~50% photon energy after CMB
- cold (10K~1THz) objects in formation
- early distant objects (dust reemission and red shift)
- deep inside (seeing through) of objects, optically thin @ THz
- rich molecular rotation lines



Good THz Sites on the Earth



credit: C. Walker



Panoramic View of the Proposed Site for ALMA at Chajnantor

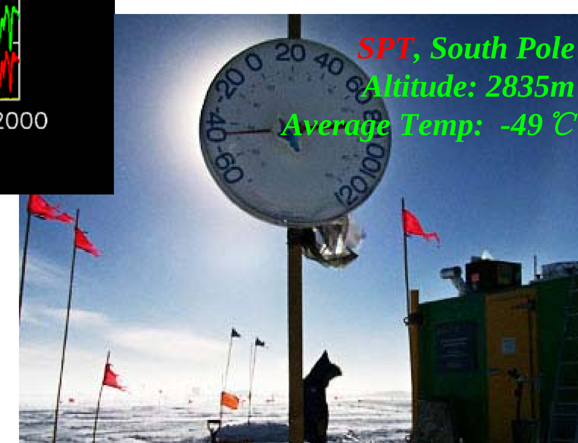
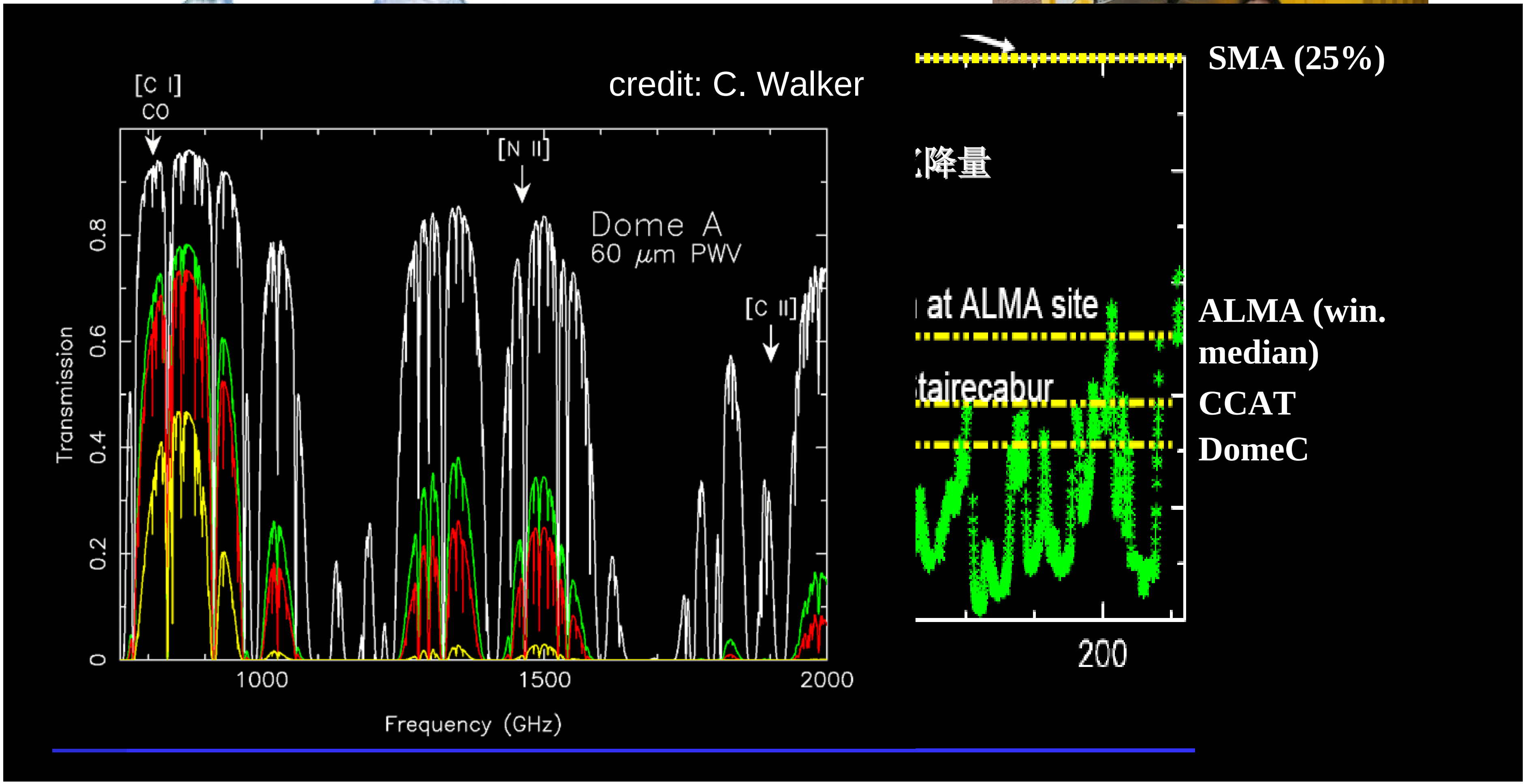


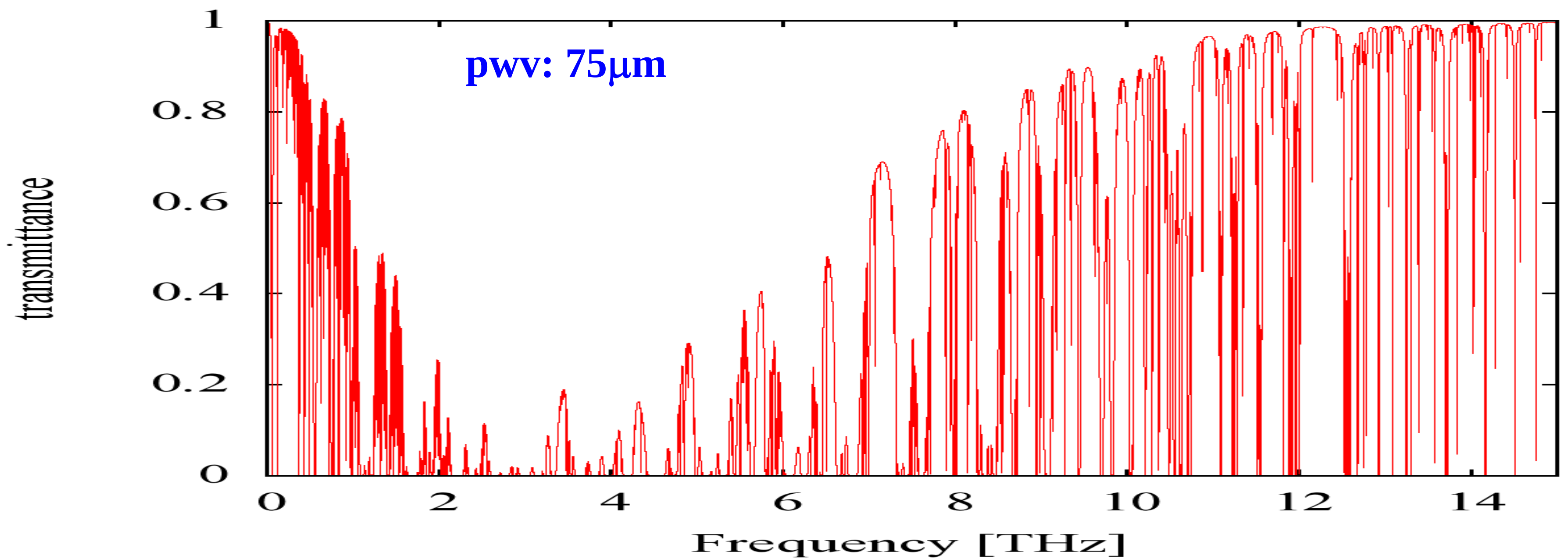
Photo Credit: Randy Landsberg

Dome A: the Best THz Site on the Earth?



FTS vs Radiometer

	Band-width	Measurement Method	Temp Calibration	Accuracy	Freq Resolution	Other Freq
Radio-meter	single freq	tipping with z, $P_{IF}(z) \rightarrow \tau_0$	not needed	good with small τ_0	high	AM needed
FTS	large	$T_{sky}(\nu)$ at fixed $z \rightarrow \tau_z(\nu)$	needed	reliable for τ up to 5	low	AM not needed



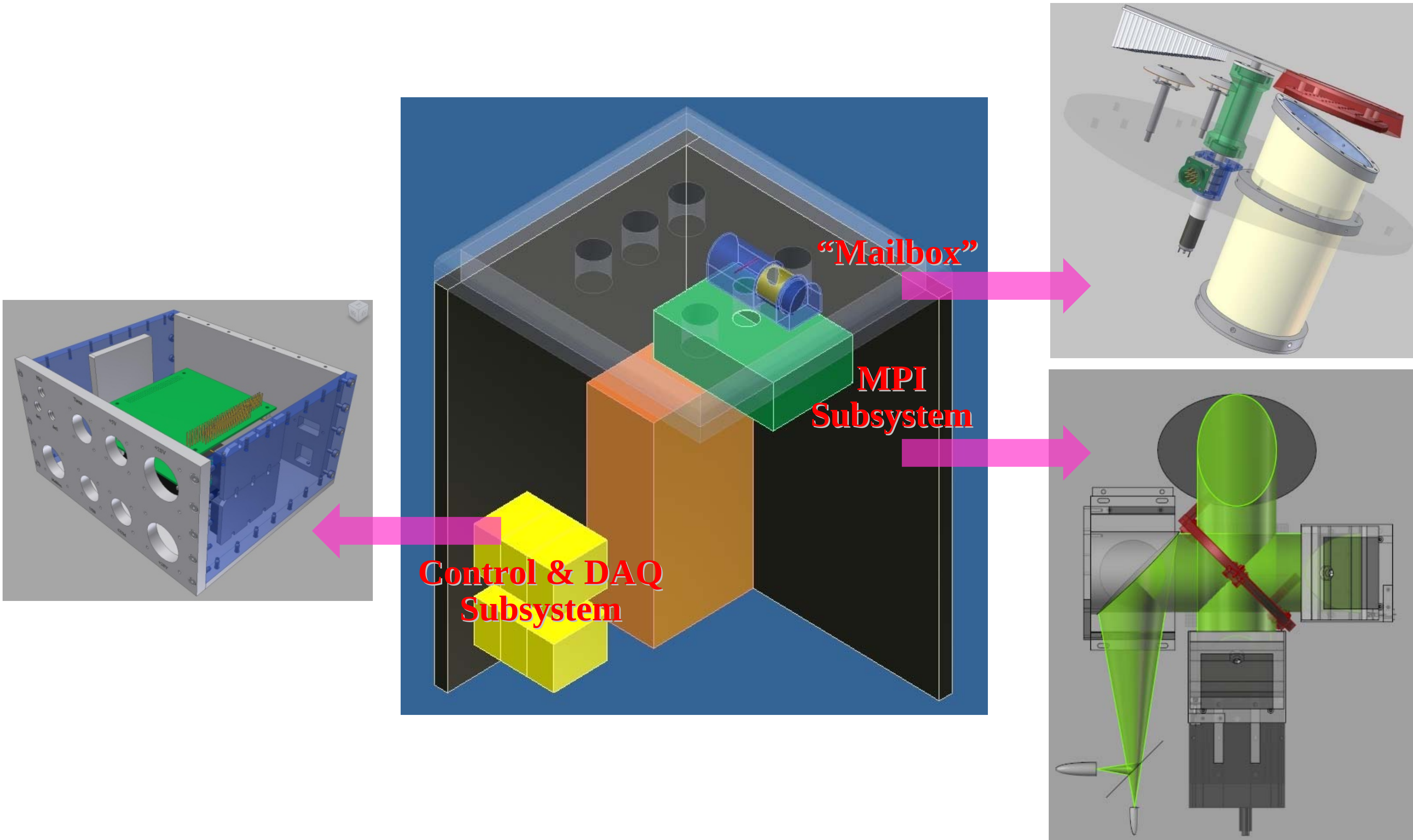
Design of the FTS System

— *Basic Requirements*

- unattended operation
- long-duration (~1yr)
- Largest bandwidth for FTSs ever used for site testing
- no LNe used → *no low-temp calibration*
- Cryogenically cooled detectors cannot be used → *limited detection sensitivity*

Design of the FTS System

— *Schematic of the System*



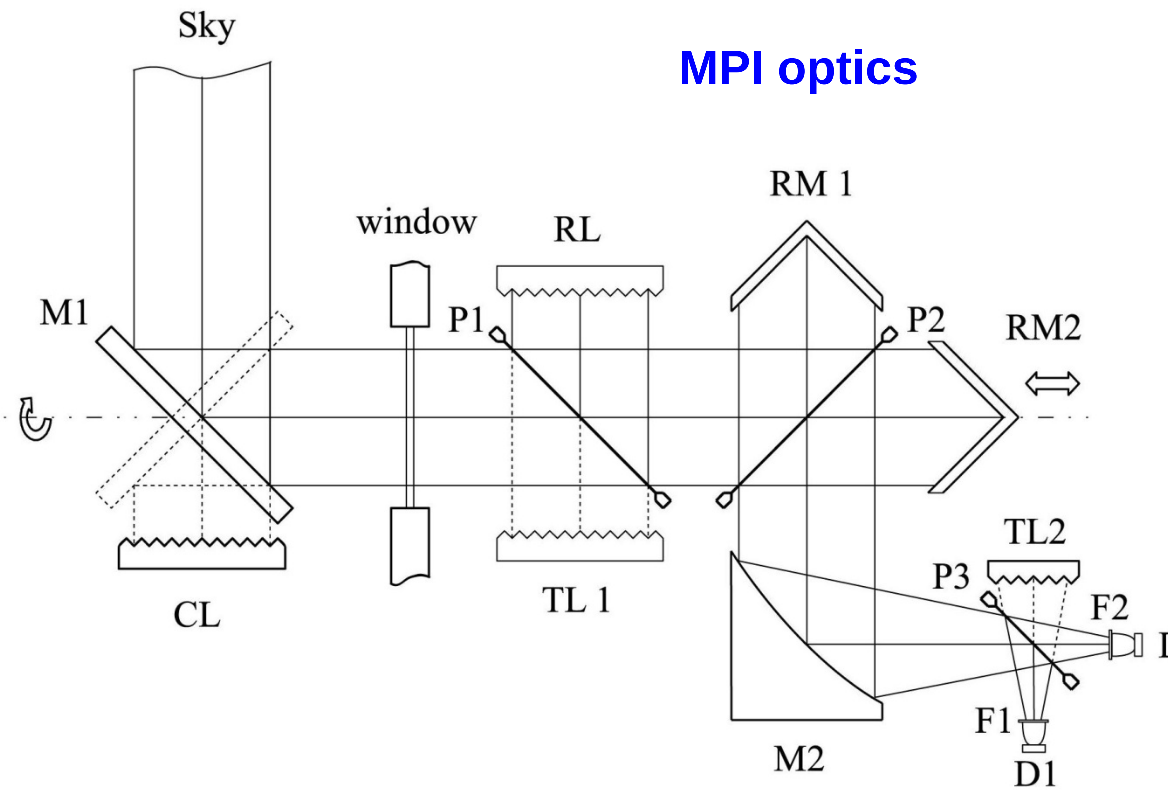
Design of the FTS System

— System Specs

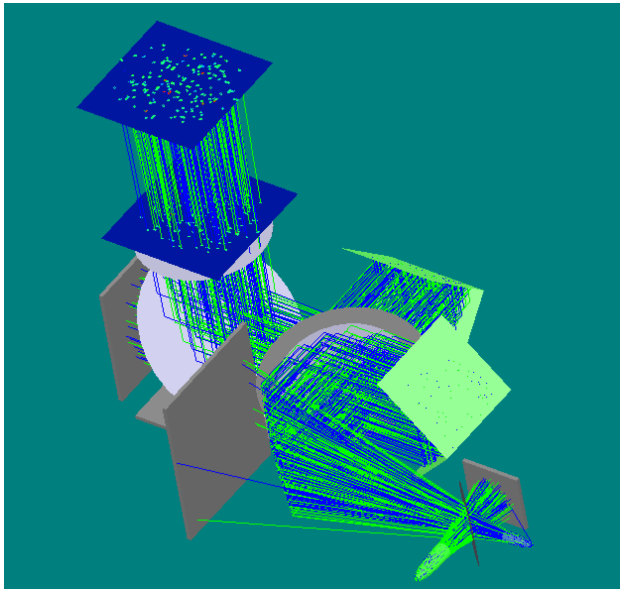
Mode	Fast scan
Freq. Range	0.75-15THz (LB: 0.75-3.5THz, HB: 3.5-15THz)
Freq. Resolution	<10GHz
Beam Aperture	>75mm
DLATGS NEP	$\sim 10^{-10}$W/Hz$^{0.5}$
Time/Spectrum	10mins
MPI Volume	0.7mx0.7mx0.3m
Power	<300W

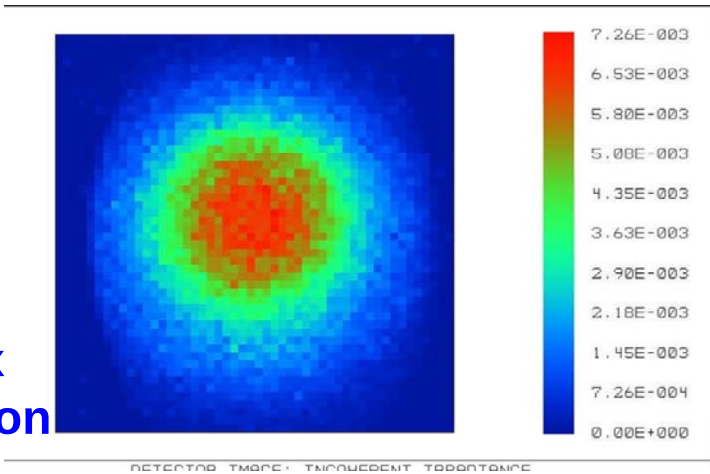
Design of the FTS System

— *Optics Calculation for MPI*



MPI optics

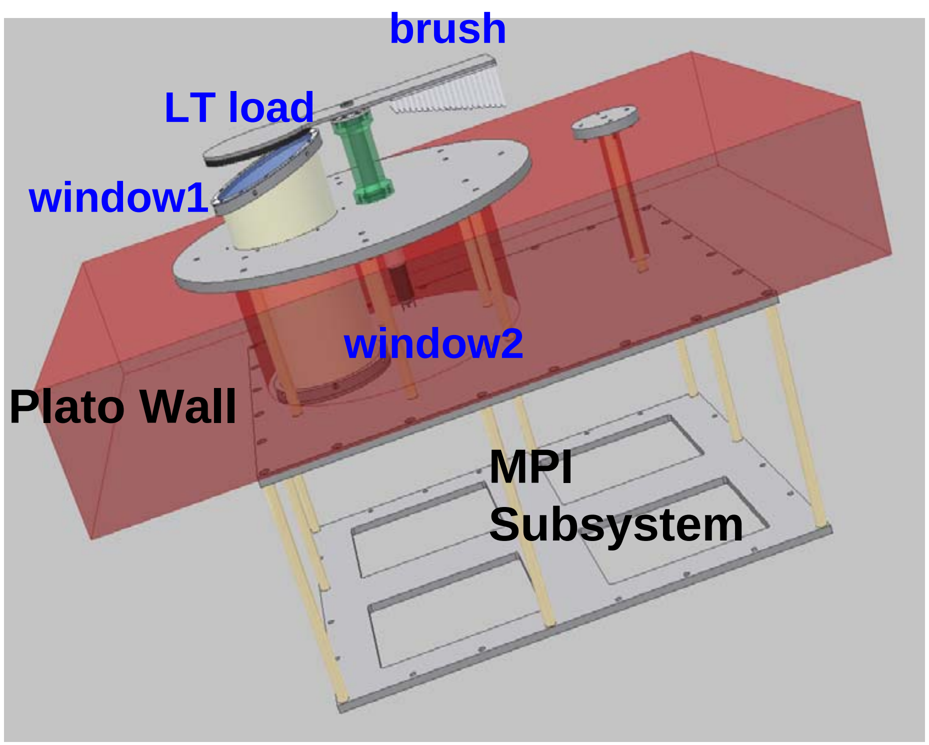




Zemax Simulation

Design of the FTS System

— "Mailbox" Subsystem



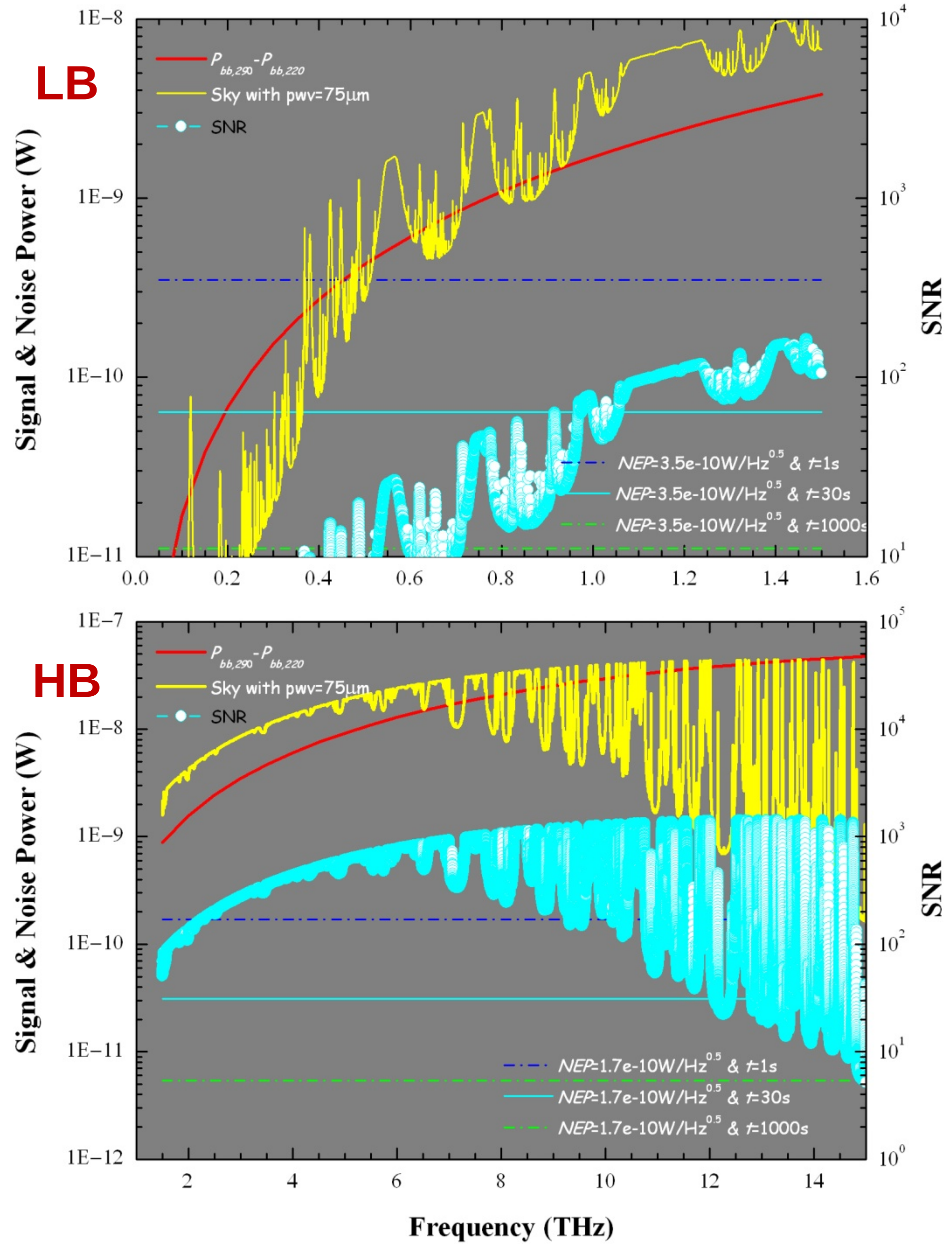
- no tipping for simplicity
- calibration load (LT) & snow cleaning structure integrated
- tilted window plus brush adopted for cleaning snow on the window
- two windows and thermal isolation adopted → less than 20W heat dispersion
- HDPE or LDPE window adopted for large bandwidth
- LT-load radiation temp precisely measured
- driver & oil specially chosen for reliability

Estimation of Sensitivity

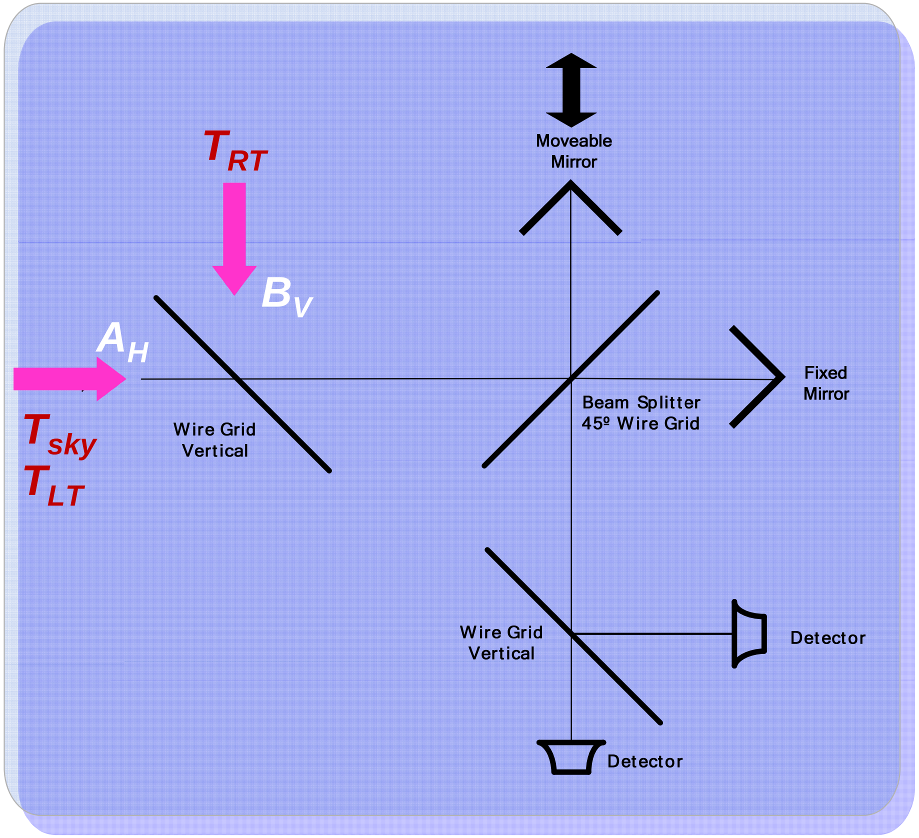
Parameters for Calculation

	Low-band	*High-band*
Freq Range (THz)	**0.5~3.5**	**3.5~15**
Resolution (GHz)	**10**	**10**
Optics Efficiency	**0.1**	**0.1**
Beam Diameter (cm)	**7.5**	**7.5**
Throughput (cm^2sr)	**0.792**	**0.185**
Detector Area (cm^2)	**0.126**	**0.029**
Detector NEP ($W/Hz^{0.5}$)	**3.5e-10**	**1.7e-10**

基于DLATGS室温探测器可实现S/N>10



Scheme of Calibration



$$P_{H,sky-RT}(z,\nu) \propto P_{H,sky}(z,\nu) - P_{V,RT}(\nu)$$
$$\propto T_{sky,RJ}(z,\nu) - T_{RT,RJ}(\nu)$$

$$P_{H,LT-RT}(\nu) \propto P_{H,LT}(\nu) - P_{V,RT}(\nu)$$
$$\propto T_{LT,RJ}(\nu) - T_{LT,RJ}(\nu)$$

z: zenith angle, ν: frequency

$$\frac{P_{H,sky-RT}(z,\nu)}{P_{H,L-RT}(\nu)} = \frac{T_{sky,RJ}(z,\nu) - T_{RT,RJ}(\nu)}{T_{LT,RJ}(\nu) - T_{RT,RJ}(\nu)}$$

$$T_{sky,RJ}(z,\nu) = \frac{P_{H,sky-RT}(z,\nu)}{P_{H,L-RT}(\nu)} \times \left[T_{LT,RJ}(\nu) - T_{RT,RJ}(\nu)\right] + T_{RT,RJ}(\nu)$$

$$S_H(x,\sigma) = \frac{1}{2}\left\{A_H^2(\sigma)\left[1+\cos(2\pi\sigma x)\right] + B_V^2\left[1-\cos(2\pi\sigma x)\right]\right\}$$
$$S_V(x,\sigma) = \frac{1}{2}\left\{A_H^2(\sigma)\left[1-\cos(2\pi\sigma x)\right] + B_V^2\left[1+\cos(2\pi\sigma x)\right]\right\}$$

$$S_H(x,\sigma) \xrightarrow{FFT} S_H(\sigma) \propto P_H(\sigma) - P_V(\sigma)$$

Control/DAQ System & Software

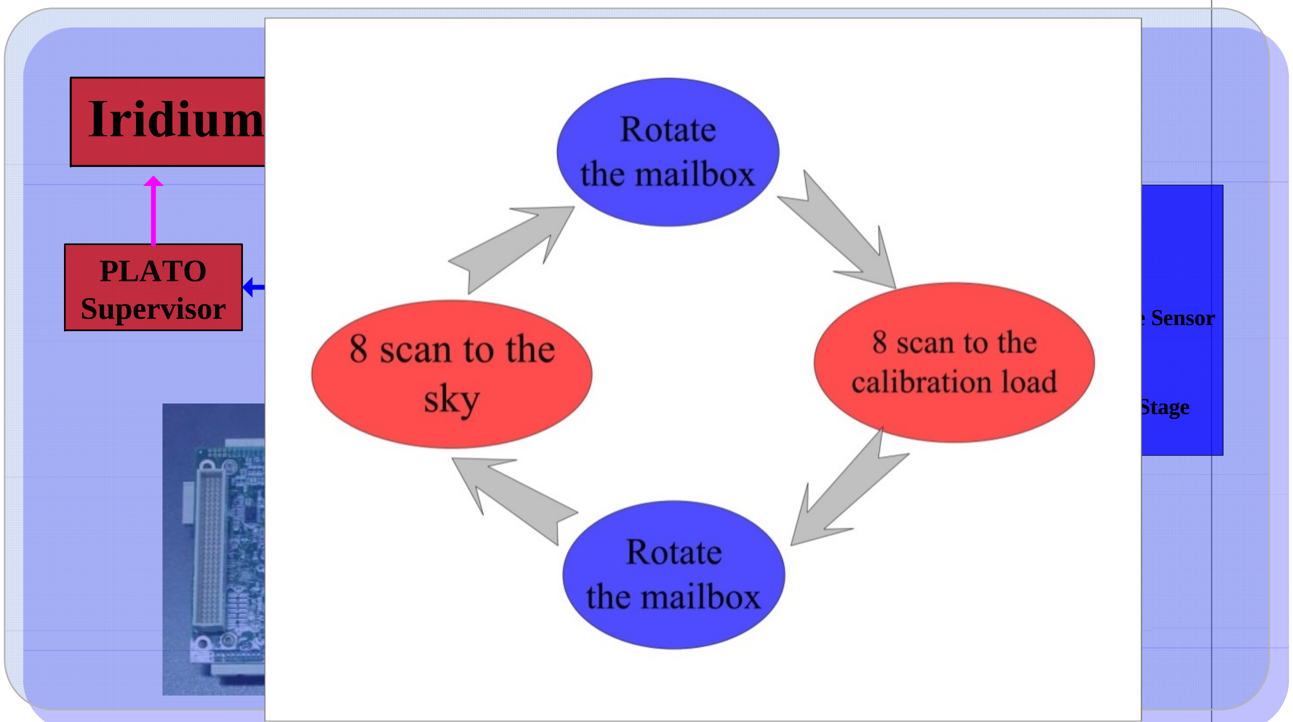
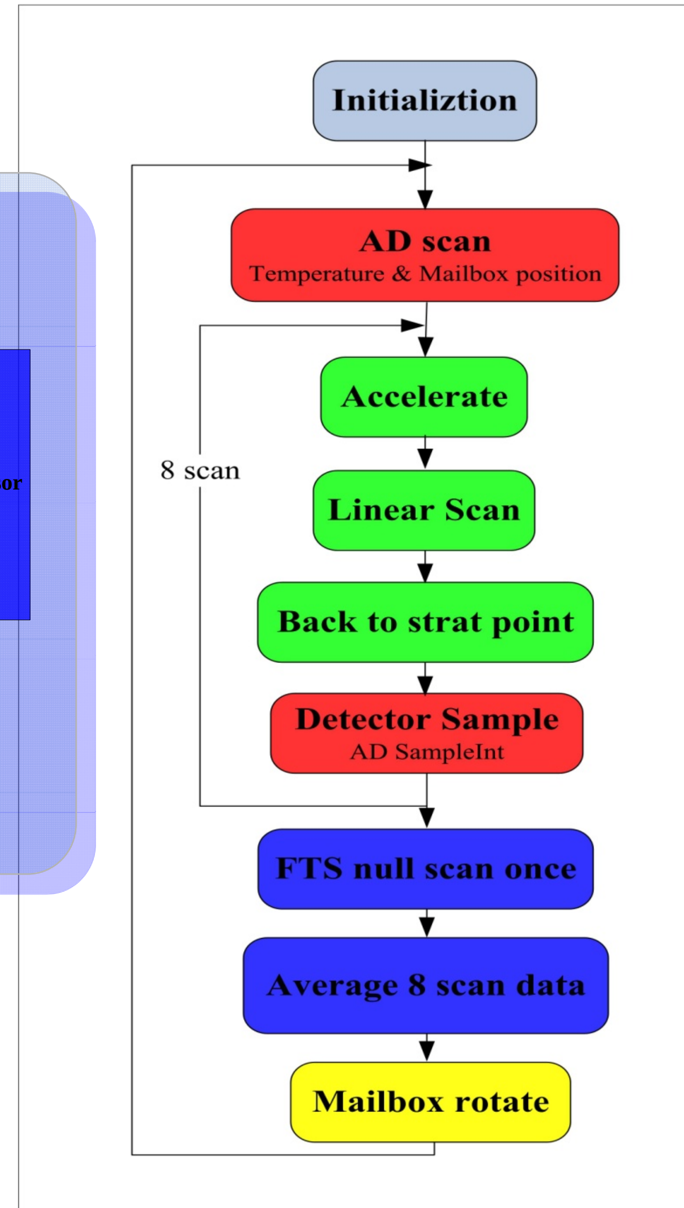


Diagram of Control/DAQ Subsystem



Timeline for FTS Development

- **End of 2008: Proposal & concept design**
- **2009/1-3: System design and contract negotiation**
- **2009/4: Contracted with QMC/Bluesky for MPI and DLATGS detectors**
- **2009/4-7: Subsystem design & starting construction**
- **2009/8: System integration & lab testing**
- **2009/9: further testing, training, preparing installation/operation manual**
- **2009/10: deploying to expedition team**

Conclusion

- A THz FTS system for Dome A has been designed,
- Fabrication of subsystems will be completed in July,
- Lab testing and training will start early August,
- Hopefully the FTS will be deployed in time for 2009 Dome A expedition

Acknowledgment

Valuable discussions with Ken Wood of QMC, D. Naylor and B. Gom of Bluesky, Plato team, and CCAA team.