Development of THz Astronomy in China

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1. Terahertz Matters in Astronomy



A Window Seeing Cold/Dark Universe













Image credits: NASA/ESA/JCMT

A Window with Rich Fingerprints



Pre-biotic signatures/building blocks of life





Ecology of ISM

A Window with Highest Spatial Resolution



II. THz Astronomy Developed in China



from space to Qinghai to Antarctic

Mm-Wave Astronomy in China



Superconducting SIS Mixers for ALMA no SIS, no ALMA



From Space to Qinghai to Antarctic



HSTDM

- 0.5-THz receiver w/ NbN SIS @ 10K
- onboard CSST w/ China's space station
- to be launched 2023/2024



15-m Submm Telescope

- Site: Qinghai
- Freq. band: 0.1~0.5/0.66 THz
- Instruments: SIS rx, KID camera, ...

THz/FIR facilities at Dome A



Atmospheric Transmission at Zenith at Three Sites



New THz/FIR Windows at Dome A

S.C. Shi et al, Nature Astronomy 1 (2016)



III. Superconducting Mixers & Detectors at PMO



High-Energy-Gap NbN SIS for Space Applications



- NbN SIS in collaboration with NiCT (Japan)
- High sensitivity @ ~ 10K
- 1st astronomical application

J. Li et al, APL 92 (2008)



Superconducting HEB Mixers: from THz to MIR

SiOx

Si





A spiral antenna NbN superconducting HEB mixer

Electron-temperature distribution on HEB



Physics:

Non-equilibrium electro-thermal transport/feedback & fluctuation

Heat balance eqs for electrons & phonons

$$\frac{\partial}{\partial x} [\lambda_e(T_e(x)) \frac{\partial}{\partial x} T_e(x)] - \sigma_{ep}(T_e(x)^{3.6} - T_p^{3.6}) + \frac{P_{LO}(T_e(x), \omega)}{2L} + \frac{I_0^2 \rho(T_e(x))}{A} = 0$$

$$\frac{\partial}{\partial x} [\lambda_p(T_p) \frac{\partial}{\partial x} T_p] - \sigma_{pp}(T_p^4 - T_{substrate}^4) + \sigma_{ep}(T_e^{3.6} - T_p^{3.6}) = 0$$



THz/MIR HEB Mixers Developed at PMO

-- in collaboration with MSPU/SRON/LERMA



First Lab Detection of 3.5-THz CH₃OH with HEB/QCL



Phase-locking & stabilized HEB/QCL System (SRON/PMO collaboration)





Y. Ren et al, APL 97 (2010); APL 98 (2011) APL 100/101 (2012)

Science Drivers with THz Camera



CMB anisotropies & PGW Imaging w/ TES & KID



Large-scale structure (e.g. EoR) LIM w/ CII,OIII, high-J CO et al Only 7 objects with spectroscopic redshift determination for z>7.5



THz "SDSS" Imaging w/ TES & KID

TES – from Mm-wave/CMB to X-Ray/IFU

Transition Edge Sensor



Physics:

Weak electron-phonon coupling & fluctuation







TES Development Status & Plan at PMO



1. THz TES

- Pixel number : 8x8
- Sensitivity : BGLP



2. Optical/NIR TES

- QE: >90%
- Energy resolution: <0.4eV
- Counting photons: >10



3. X-Ray TES Micro-Calorimeter

- Band: 0.3-7/12keV
- Energy resolution: <5eV
- Pixel number: >1k

KID – from THz 2D/3D to Optical Imaging

1k pixel KID chip



First KID Camera Developed in China



THz Spatial-Spectral 3D Imaging (LIM) with KID



Device Fabrication Facility at PMO





TES

Thank You !