Chinese Antarctic Observatory

-- Latest Developments for DATE5

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Outline

• Introduction
• DATE5 Telescope
• THz Superconducting Receivers
• THz Superconducting Imaging Array
• Conclusions
Where is Dome A?

Basic facts about Dome A

- Altitude: 4093m (60km×10km)
- Lowest temp: -83°C
- A plateau of small fluctuation
- 1300km from China’s Zhongshan station
- Extremely good THz/IR windows
Major Relevant Features

- Low water content (good for THz observations, and precision photometry)
- Low scintillation error (good for precision photometry)
- Continuous observing (good for time domain astronomy)
- Low atmospheric boundary layer (good for high spatial observations, seeing ~ 0.3 arcsec)
- Low temperature (good for IR observations)

- Aurora
- High relative humidity
- Difficult to access
- Less dark time
Dome A FTS & Results

Transmission~0.4 @ 1.5THz
Dome A Observatory – Roadmap

2006-2008
Site Survey & Small Telescope

2009-2011
+Site Testing & Middle-size Telescope

2011-2015
Dome A Observatory Phase I

2016-2025
Dome A Observatory Phase II

2.5m Opt/NIR KDUST

5m THz DATE5

6-8m Opt/NIR

15m THz
Dome A 5m THz Telescope (DATE5)

- **Antenna**: Cassegrain
- **Diameter**: 5m, with rms accuracy <10µm
- **Receiver**: 1x4 superconducting SIS & HEB mixer
- **Band**: 350µm & 200µm
- **IF BW**: 4GHz x 4 beams x 2 bands
- **FOV**: 5’×5’ (200µm)
- **Pointing**: ≤2"

**Diagram:**
- **Antenna Subsystem**: Antenna → Quasi Optics
- **Rx Subsystem**: Frontend Unit (H350 & H200) → IF Unit (4GHzx8)
- **Remote Control Subsystem**: FFTS (4GHzx8)
- **Dome A 5m THz Telescope (DATE5)**

**Preliminary Design of DATE5**
Major Science Cases for DATE5

- Galaxy formation and evolution
- Life cycle of stars/interstellar medium
- Origin of planetary systems
Quasi-Optics & Rx of DATE5

All integrated in a 4K cryostat

inside view
1.4THz Supercond HEB Mixer

H200 HEB mixer

H200 HEB mixer chip

TEM image of the HEB microbridge

NbN film thickness ~5.5nm

NbN

5.5 nm

SiOx

Si
1.4THz Supercond HEB Mixer

Measured and simulated near-field and far-field beam patterns @ 0.85THz

Noise temperatures (uncorrected) measured @ 0.85THz & 1.26THz

Trec=2000K @0.85THz

Trec=650K @1.26THz
0.85THz Supercond SIS Mixer

1x4 beam H350 SIS mixer

H350 waveguide SIS mixer circuit
A 2GHz Bandwidth FFTS

Diagram of 2GHz-bandwidth FFTS

Allan variance time: ~ 2000s

Dynamic range: ~ 30dB
THz QCL Integrated with HEB

Combined THz QCL & HEB with a Gas Cell for the detection of 3.5THz methanol line


SRON/TUDelft
PMO
MIT

THz QCL Integrated with HEB

Measured 3.5THz methanol line
Development of 4K Cryocooler of Low-Power Consumption

Developed jointly with SHI Shanghai, with the help of SHI Japan
Goal: 1) ~3kW power consumption,
2) able to operate at low temperatures about -20°C and to store at low temperatures about -40°C

Latest cooling result

<table>
<thead>
<tr>
<th>SHI RDK-205D</th>
<th>0.5W @ 4.2K</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>5W @ 40K</td>
</tr>
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</table>

![Graph showing 2nd Stage Temperature of Cryocooler @0.3W vs Input Power/kW](image)
THz Superconducting Imaging Array (TeSIA)

<table>
<thead>
<tr>
<th>Detector</th>
<th>TES or MKIDs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Array size</td>
<td>32x32</td>
</tr>
<tr>
<td>Band</td>
<td>350µm</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>BGLP, 1x10^{-16}W/Hz^{0.5}</td>
</tr>
</tbody>
</table>

- **Quasi-optics**
- **TES/MKIDs**
- **LT MUX**
- **RT MUX**
- **0.3K/4K Cryocooler**
- **DAQ/Control**
TeSIA Developed with TES

TES Array (8x8 @ 850um) with TDM
Ti & NbSi Superconducting TES

Measured R-T for Ti (l) & NbSi (r) devices
Ti & NbSi Superconducting TES

**Ti TES**

- $G = 170 \sim 280 \text{ pW/K}$
- $\text{NEP}_{\text{dark}} \approx 6.5 \times 10^{-17} \text{W/Hz}^{0.5}$

**NbSi TES**

- $G = 345 \text{ pW/K}$
- $\text{NEP}_{\text{dark}} \approx 5.4 \times 10^{-17} \text{W/Hz}^{0.5}$
TeSIA Developed with MKIDs

MKIDs Array (8x8 @ 850um) with FDM

Control Computer
Ext. Source
10 MHz Sync

AWG
Comb Signal Generating

FPGA
Signal Processing

0.1~500MHz

IF Circuit Board

LPF

Synthesizer

LNA

IQ Mixer

Attenuator

Baseband LNA

Attenuator

IF LNA

Cryostat

KIDs Array

HEMT LNA

4~8.5GHz
Measured 8x8 TiN MKIDs

Measured S21 vs T & P
Typical Q~$10^4$
Prototype To Be Tested on POST

QMC Dewar

Windows

Lens Array

HDPE Lens 1

HDPE Lens 2
A Newly Built Clean Room Facility

Mask Aligner

Sputtering Cluster

ICP Etcher

Graph showing resistance (ohm) vs. temperature (K) for Nb on SiO₂.

Graph showing current (mA) vs. voltage (mV) with different line styles for various thicknesses of material.
Conclusion

Atmospheric transmission from 0.75-15 THz measured directly ever at Dome A, which is a rather promising site for THz astronomy,

First generation instrument for DATE5 telescope will be two heterodyne receivers, and a 32x32 superconducting imaging array at 350 μm (TeSIA) is under development,

TeSIA is developed with TES and MKIDs, with TESs demonstrating a dark NEP better than 10-16 and MKIDs a reasonably high quality factor,

Prototype imaging array (850 μm ) will be demonstrated on POST in 1~2 years.
Acknowledgment

- CAS & NSFC funding for DomeA Projects
- CCAA, Polar Institute (China) & PLATO Team (NSWU) for the deployment & operation of DomeA FTS
- Blue Sky (Canada) and QMC (UK) for good cooperation in developing DomeA FTS
- Team for CAS’s Int. Collaboration Partnership Program (PMO, CfA, ...)
- APC/IAS/ASIAA for the fabrication of TES devices
- RIKEN for the fabrication of MKIDs devices