

Welcome and Introduction

Ninth International Symposium on Space Terahertz Technology

Carl Kukkonen

Director, Center for Space Microelectronics Technology

JPL

March 17-19, 1998

SUBMILLIMETER AND THZ DRIVERS

- **ASTROPHYSICS**

**Long awaited major observation platforms, SOFIA, and
FIRST now close to reality.**

- **EARTH ATMOSPHERIC CHEMISTRY**

EOS-MLS now in Phase C/D

- **PLANETARY AND COMETARY SCIENCE**

- **LABORATORY SPECTROSCOPY**

Terahertz Astrophysics Observing Platforms

- **Far Infrared Submillimeter Telescope (FIRST) - ESA Mission**
Proposal submitted for heterodyne instrument, February 15, 1998
Joint European / US Instrument Team

Baseline Capabilities

- Passively cooled 3.8 m telescope
- 480-1250 GHz SIS mixers
- 1.4-1.9 THz and 2.4-2.7 THz HEB mixers
- High resolution spectroscopy 85-600 μm , photoconductor and bolometer arrays
- Broad band photometry 85-900 μm bolometer arrays

NASA Contributions

- Orbit: Increase observing time and sensitivity
- 3.8 m telescope
- 3 receiver bands: SIS 1.0-1.2 THz; HEB 1.4-1.9 THz, & 2.4-2.7 THz
- MMIC Power amps for LO system
- InP HEMT's for IF system

Terahertz Astrophysics Observing Platforms

The Stratospheric Observatory for Infrared Astronomy (SOFIA)

- **Joint US / German Project**
- **2.5 m aperture airborne telescope for wavelengths between 0.3 μm and 1.6 mm, with emphasis on submillimeter and far-IR**
- **First round of instruments selected and under construction
(A Submillimeter and Far-Infrared Heterodyne Receiver)**
- **First flights in 2001**
- **20 year lifetime**
- **USRA, Raytheon E-Systems, United Airlines**

Terahertz Astrophysics Observing Platforms

- **Submillimeter Wave Astronomy Satellite (SWAS)**
 - Small Explorer Mission
 - Heterodyne receivers near 480 and 560 GHz
 - Observe interstellar water, oxygen, and carbon
 - Launch date 1998
- **Antarctic Submillimeter Telescope and Remote Observatory (AST/RO)**
 - South Pole Observatory operational this year funded by NSF
 - 1.7 m aperture for 0.5 mm wavelengths
 - Built, running and taking data
- **Heinrich Hertz / Submillimeter Telescope Observatory (HHT/SMTO)**
 - Located on Emerald Peak of Mt. Graham, approximately 75 miles north-east of Tucson, Arizona
 - 10 m aperture for wavelengths between 1.3 mm and 350 microns
 - Joint University of Arizona / Max-Planck Institut fur Radioastronomie project
 - Operational and taking data

Terahertz Astrophysics Observing Platforms

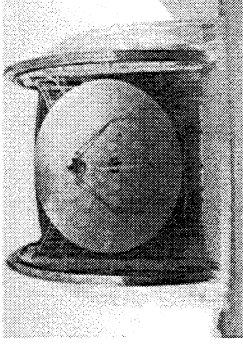
- **NRAO - Millimeter Array in Chile**
 - 32 Telescopes (64 with European collaboration)
 - 10 m diameter (12 m with European collaboration)
 - Construction start 2001
 - Operational 2007
 - Frequency: 30 -950 GHz

- **South Pole 10 m Telescope**
 - Operational 2003
 - AST/RO - NSF Funded Program
 - SIS & Bolometers up to 1.5 THz

Terahertz Astrophysics Observing Platforms

- **Microwave Instrument for the Rosetta Orbiter (MIRO)**
 - Approved for the Rosetta Orbiter - Launch 2003
 - Currently in Phase B: Proto-flight models under development
 - Two channel continuum and spectroscopic heterodyne receiver system
 - Submillimeter Wave Receiver - Frequency: 540 GHz
 - Millimeter Wave Receiver - Frequency: 190 GHz
 - RFP for flight subsystems in 1998
- **Submillimeter Array (SMA)**
 - Harvard Smithsonian Center for Astrophysics
 - 6 telescopes, upgrade to 8
 - 6 m diameter
 - On Mauna Kea, Hawaii
 - Operational 2000
 - Operational frequency range: 200 - 800 GHz

Terahertz Astrophysics Observing Platforms



- **Caltech Submillimeter Observatory**
 - A cutting-edge facility for astronomical research and instrumentation development
 - Located on "submillimeter ridge" near the summit of Mauna Kea, Hawaii
 - 10 m Telescope
 - Frequencies: 230 - 950 GHz



- **Owens Valley Radio Observatory**
 - Largest university-operated radio observatory in the world
 - Located five hours north of Pasadena, near the Sierra Nevada range
 - Six 10m telescopes
 - Frequency ranges 80-116 GHz and 210-270 GHz
 - 40m Telescope
 - 5m Telescope
 - Two 27m Telescopes

Status of NASA Submillimeter Sensors Astrophysics Program

- **Superconducting Mixers**
 - Nb SIS Mixers meet needs of FIRST for frequencies up to 1 THz
 - Challenge is to improve performance to 1250 GHz
 - Approach: NbTiN SIS mixers
 - Above 1.4 THz: Use Hot Electron Bolometer Mixers
 - Approach: Diffusion Cooled (Nb, Al)
- **Solid State Local Oscillator Sources**
 - Multiplier chains meet power requirements of FIRST for frequencies up to about 1.2 THz
 - Challenge is to provide
 - Wide bandwidth with fixed tuning
 - Reliability
 - Higher Power and Stable Photomixer L.O. (1-3 THz)

NASA Terahertz Space Missions for Earth Observations

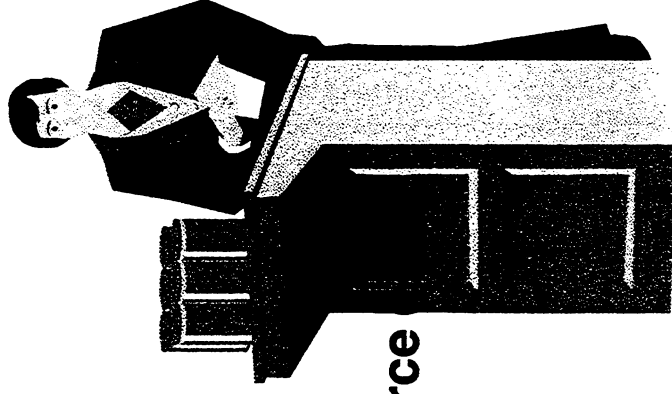
- **Earth Observing Satellite Microwave Limb Sounder**
Study of chemistry of stratospheric ozone on a global scale
 - 118 GHz
 - Temperature and Pressure
 - 190 GHz
 - Continuity with UARS MLS for O₃, ClO, and H₂O
 - 240 GHz
 - O₃, CO - Temperature and Pressure
 - 640 GHz
 - Ozone chemistry (O₃, HCl, ClO, NO₂ and others)
 - 2.5 THz
 - Ozone chemistry (OH), Temperature and Pressure
- **Approved mission, Phase C/D began January 1998;
instrument engineering model build in 1998**
- **Launch date 2002**

Status of NASA Submillimeter Sensors Earth Remote Sensing Program

- **EOS Microwave Limb Sounder is beginning Phase C/D Receiver Engineering Models to be delivered 1998.**
- **Major development thrust areas include:**
 - **Planar Schottky diode waveguide harmonic mixers up to 640 GHz**
 - **Planar Schottky diodes & integrated mixer circuitry for 2.5 THz**
 - **Planar varactor diode waveguide multipliers up to 320 GHz**
 - **Superconducting high- T_c diffusion cooled bolometer mixers**
 - **Laser diode pumped photomixers for THz LO generation**
 - **CO₂ pumped gas lasers for high power THz LO generation**
 - **High frequency GUNN oscillators**
 - **Low power digital autocorrelators**
 - **1-20 GHz ultra low noise HEMT amplifiers**
 - **MMIC power amplifiers**

Kukkonen Challenge 1993

- **First SIS mixer with**
 - Frequency > 1 THz
 - $T_{\text{sys}} < 1000 \text{ K DSB}$
- **First Solid State Local Oscillator Source**
 - Frequency > 1 THz
 - Output power > 100 microwatts
(100 GHz Bandwidth) Unclaimed



Awarded 1995

1997 Kukkonen Challenge

Local Oscillator

Frequency: 1-3 THz (500 GHz Tunability)

Power: 10-50 μ watts

Unclaimed

