Center Reports

Center for Terahertz Science and Technology
Annual Report for July 1, 2003 to June 30, 2004.

The field of Terahertz science and technology is gaining international prominence as a result of a confluence of factors. First, there have been recent breakthroughs in the development of compact, solid-state sources of THz radiation, including notable progress at UCSB (see research highlights). Second, a number of accelerator facilities and accelerator-based light sources have discovered that they can relatively easily generate copious quantities of THz radiation. Third, there is a current interest and intensive research into imaging with THz radiation, with potential applications ranging from medicine to industrial quality control to security screening.

UCSB is extremely well-positioned in this field with respect to both basic science and applications. Faculty directly involved in Terahertz research include Jim Allen (Physics), Elliott Brown (Electrical and Computer Engineering), Andrew Cleland (Physics), Art Gossard (Materials and ECE), Phil Lubin (Physics), Kevin Plaxco (Chemistry and Biochemistry), Mark Rodwell (ECE), and Mark Sherwin (Physics).

This year, I co-organized with Phil Bucksbaum (Physics Dept., University of Michigan) and Charles Schmuttenmaer (Chemistry Dept., Yale) a Workshop on THz Science, co-sponsored by the DOE, NSF and NIH. The workshop took place Feb. 12-14, 2004 in Arlington, VA and resulted in a report which has had some impact. The report can be found on the Department of Energy's Basic Energy Sciences website at http://www.sc.doe.gov/bes/reports/list.html.

The UCSB Free-Electron Lasers are enabling fundamental research and technology development that can be done nowhere else. During this fiscal year, we were awarded a three-year Major Research Instrumentation grant from the NSF to upgrade the UCSB FELs in significant ways. One main goal is to upgrade the control system for the FEL to make it more stable, user-friendly, have higher resolution, and ultimately double the high-frequency end of the FEL's tuning range from 5 to 10 THz. Other goals are to improve FEL diagnostics and to narrow the linewidth of the FEL by locking its frequency to that of a very stable, low-power source.

General statistics regarding the FEL's use and productivity can be found on the next page. The increasing prominence of the field of THz Science and

Technology has increased the visibility and number of outside groups wishing to use UCSB's FELs.

The research highlight I have chosen for this year is described in an article entitled "Resonant Crossover of Terahertz Loss to the Gain of a Bloch Oscillating InAs/AlSb Superlattice" by P. G. Savvidis, B. Kolasa, G. Lee and S. J. Allen (Phys. Rev. Lett. **92**, 196802). One of the "holy grails" of Terahertz technology is to make a compact source of THz radiation which operates at room temperature and is driven by current flowing through two electrical terminals—a laser pointer that emits at THz frequencies, if you will. Previous work using the UCSB FELs hinted that, when current flowed through a semiconductor superlattice (alternating layers of semiconducting material with different affinities for electrons), amplification of THz radiation, or "gain," should be possible under special conditions. However, the evidence for gain came from interpretation of features in a plot of current vs. voltage across the superlattice while it was irradiated with THz radiation. This year's highlight is a much more direct measurement which shows that, under conditions in which one expects gain, the THz transmission of a DC-biased superlattice is enhanced. This work is attracting considerable attention. The work was done as a collaboration between Prof. Allen's group and a group at Agilent Laboratories.

Summary statistics for CTST, 2003-2004.

Research and development projects:

1. Terahertz electro-optics in semiconductor nanostructures
2. Quantum-limited Terahertz detection without Liquid Cryogens
3. Optical Manipulation of Quantum Information in Semiconductor Nanostructures.
4. Development of a THz source based on Bloch oscillation in semiconductor superlattices.
5. Unbiased, in-situ Life Detection TechnologyBased on Terahertz Circular Dichroism
6. Biological Sensing with Terahertz Circular Dichroism Spectroscopy
7. Submillimeter-Wave Circular Dichroism Spectroscopy of Biomaterial in Water
8. Development of a Laser Driven Terahertz System to Study Material and Devices, and Student Training.
9. Development of a Stable, User-Friendly, High-Power Terahertz Source: Enhancements to the UCSB Free-Electron Lasers.

Number of research publications: 9

Number of invited talks: 13
Number of FEL hours logged: 2,125

FEL users from UCSB:

- Graduate student researchers:
  - Matt Doty (Advisor: Sherwin)
  - Sam Carter (Sherwin)
  - Markus Ansmann (Sherwin)
  - Jing Xu (Allen, Plaxco)
  - Borys Kolasa (Allen)
- Post-doctoral researchers:
  - Brendan Serapiglia (Sherwin)
  - Victoria Ciulin (Sherwin)
  - Pavlos Savvidis (Allen)

FEL users from outside UCSB:

- Prof. James Heyman (Macalaster College, St. Paul, MN)
- Agilent Labs
- Tomas Feil (University of Regensburg, group of Prof. W. Wegscheider)
- Raytheon
- Prof. Martin Koch (three month sabbatical from Technical University of Braunschweig, Germany)