# Nanostructure Enhanced Terahertz Technology for Sensing and Imaging

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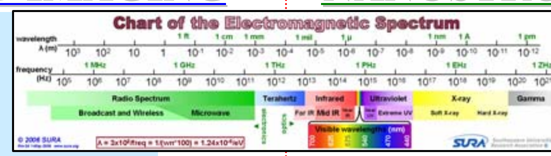
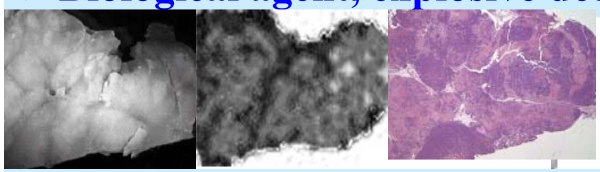
## TERAHERTZ FOR SENSING AND IMAGING

- Material fundamental properties studies (metamaterials, quantum nonlinear dynamics)
- Biomedical imaging
- Gas sensing, gas phase spectroscopy
- Biological agent, explosive detection



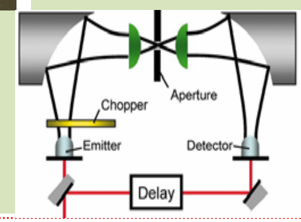
Biomedical imaging, S.M. Kim et al, (2005)

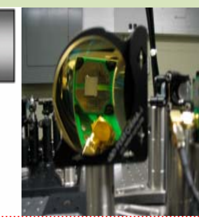
## NANOSTRUCTURE SYNTHESIS AND CHARACTERIZATION

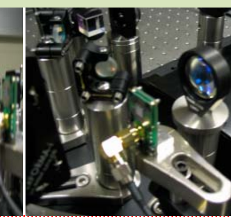
- Unique custom designed MOVPE reactor
- Specifically designed for wide bandgap semiconductors and nanostructures

**THz-TDS System:**

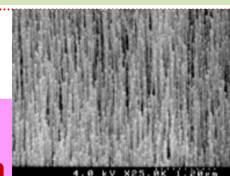
- Broadband THz signal upto 3THz
- High dynamic range





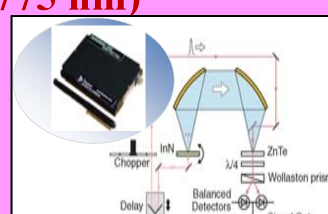
## III-NITRIDE NANOSTRUCTURES and COMPACT THz SOURCES




- Nanowires/rods have a significantly increased smooth emitting surface area
- Diameters can be on the order of the accumulation layer thickness.

**Advantages of InGaN for THz:**

- Engineerable bandgap (λ=365~1775 nm)
- High saturation & peak drift velocity
- Short carrier lifetime
- High breakdown electric field



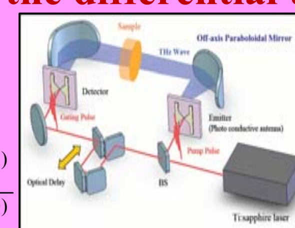

## THz NANOSTRUCTURE CHARACTERIZATION

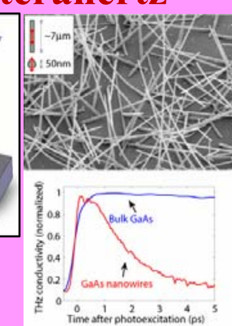
- The time-resolved photoinduced conductivity can be obtained from the differential terahertz transmission

$$|\Delta\sigma(\tau)| = \frac{1+n_s}{\delta Z_0}\frac{\Delta T}{T}$$

$$T(\omega) = \frac{E_S(\omega)}{E_r(\omega)} = \frac{|E_S(\omega)|}{|E_r(\omega)|}\frac{e^{i\phi_s(\omega)}}{e^{i\phi_r(\omega)}}$$

$$\Delta n(\omega) = -\frac{cd}{\omega}\left[\phi_s(\omega) - \phi_r(\omega)\right]$$



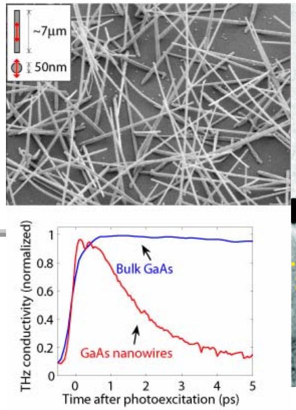



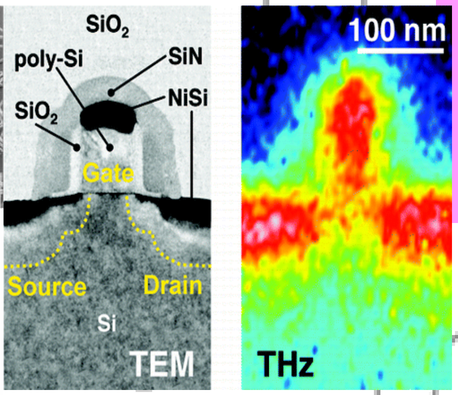

Parkinson et al, (2007)

- New method of nanomaterials characterization:charge transfer in photovoltaic solar cell

# THz NANOSTRUCTURE CHARACTERIZATION

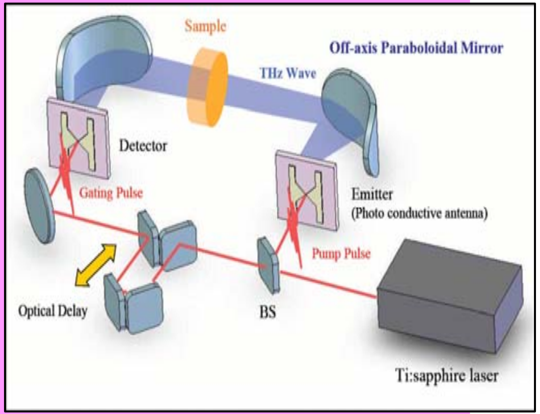
**Being a non-contact optical method, THz time domain spectroscopy is an ideal method to characterize the electrical properties of semiconductor nanostructures, including carrier densities and conductivity.**




Parkinson et al, Nano Lett. (2007)
A. Huber et al, Nano Lett. (2008)

- **The time-resolved photoinduced conductivity can be obtained from the differential terahertz transmission**




$$\left|\Delta\sigma(\tau)\right| = \frac{1+n_s}{\delta Z_0}\frac{\Delta T}{T}$$

$$T(\omega) = \frac{E_S(\omega)}{E_r(\omega)} = \frac{\left|E_S(\omega)\right|}{\left|E_r(\omega)\right|}\frac{e^{i\phi_s(\omega)}}{e^{i\phi_r(\omega)}}$$

$$\alpha(\omega) = -\frac{2}{rd}\ln\frac{\left|E_S(\omega)\right|}{\left|E_r(\omega)\right|}$$

$$\Delta n(\omega) = -\frac{cd}{\omega}\left[\phi_s(\omega) - \phi_r(\omega)\right]$$

- **Application of various THz spectroscopy technology**
- **New method of nanomaterials characterization:**
  - **-Nanomagnetic materials, spintronic devices**
  - **-Probe for charge transfer in photovoltaic solar cells**
  - **-Carbon Nanotube**