Study of Terahertz Emission from MoS_2 Interdigitated Antennas

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We study the THz emission properties of interdigitated THz antennas using MoS2 as the conductive medium. Given the recent discovery of a direct bandgap and the resulting photoconductive properties of monolayer MoS2, THz emission from these antennas have the potential for technological and commercial improvements over current GaAs antennas. This poster will show the fabrication process of interdigitated antennas using MoS2, as well as the design and construction of a terahertz time-domain spectrometer to study THz emission. The properties of the THz spectrometer are first characterized using interdigitated GaAs antennas, and current progress in studying the THz emission from the MoS2 antennas will be discussed.

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Purpose: We study the THz emission properties of interdigitated THz antennas using Molybdinum Disulphide(MoS_2) as the conductive medium. With the recent discovery of a direct bandgap and the photoconductive properties of monolayer MoS2, Terahertz (THz) emission from these antennas have the potential for technological and commercial applications. This poster discusses our current progress in the fabrication process of interdigitated antennas using few- to mono-layer flakes of MoS_2, as well as the design and construction of a terahertz time-domain spectrometer to study THz emission.

Antenna Fabrication

1) Printing the layers of an antenna (see figure 1). The full procedure is listed below:

- 1 cm^2 silicon/silicon dioxide substrates were cleaned.
  - Acetone bath followed with isopropanol (IPA) rinse.
- Substrates exposed to MoS_2
  - Liquid-phase exfoliated drop cast (See figure 2).
  - Chemical Vapor Deposition (CVD) (See figure 3).
  - One dummy cell- no exposure
- Photoresist spin coated at 1μm
- Maskless Lithography followed with development of the substrates.
- First layer of Ti/Au at 1:10 ratio (Used 6:60 nm coating)
- Lift off: samples submerged in acetone to dissolve remaining photoresist and 'lift off' the gold on those areas.
  - IPA rinse and dried with N_2
- Photoresist applied a second time followed by maskless lithography and development
- SiO_2 deposition via CVD (400-500 nm)
  - Lift off repeated
- Photoresist applied a final time, maskless lithography, and development
- Ti/Au coating (same thicknesses used before)
  - Lift off procedures

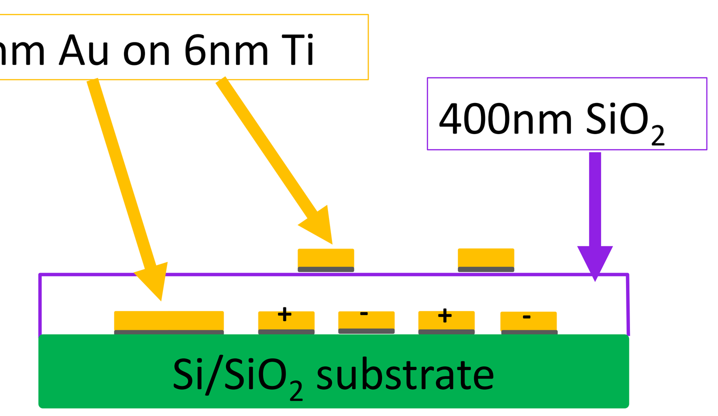

Figure 1: A basic schematic of the layering of the antennas.

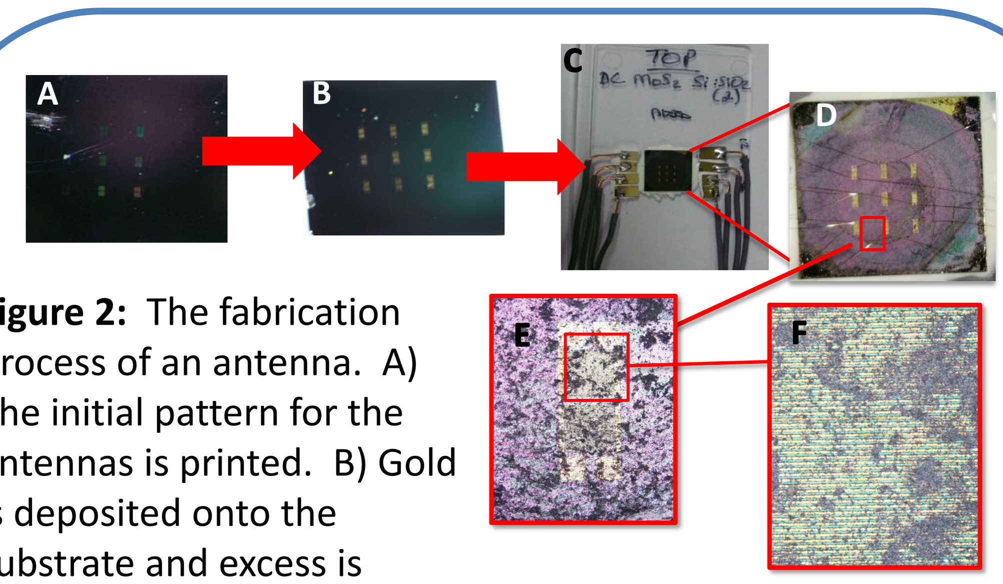

Figure 2: The fabrication process of an antenna. A) The initial pattern for the antennas is printed. B) Gold is deposited onto the substrate and excess is removed. Processes A& B are repeated for a SiO_2 layer and another gold layer. C) The final devices (drop cast MoS_2 sample imaged here) are secured to a base plate and wire bonded to larger contact pads. D) Magnified image of the wire bonded substrate. E) Image of a pair of antennas magnified at 10x. F) Image of fingers of the antenna 50x magnification.

2) Characterization of the printed antennas:

- Probe station used to identify working antennas (a resistance on the order of mega ohms is required to constitute a working device.

3) Finalization of the antennas:

- Entire substrate glued to a base plate with large contact pads
- Wire bonding done between large contact pads and small contact pads on the antennas.
- Contact pads soldered to wires and loaded into spectrometer for testing.

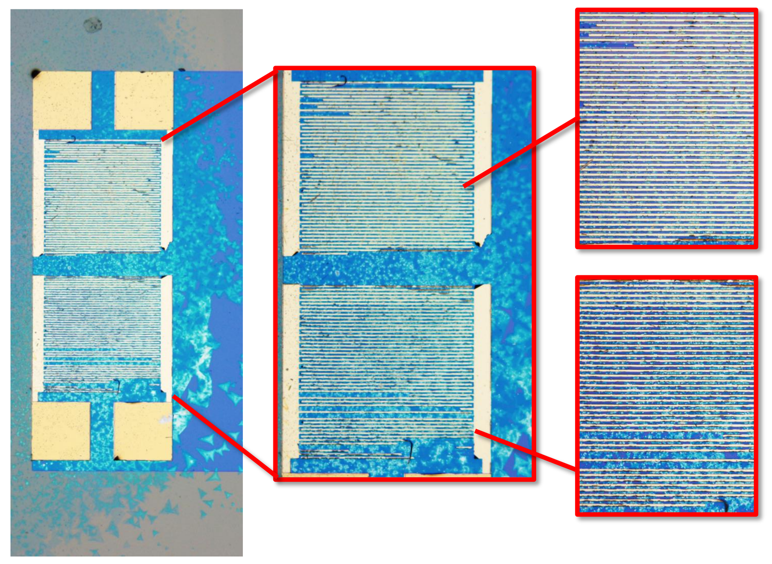

Figure 3: Images of antennas printed on CVD grown MoS_2 at 10x, 20x, and 50x magnification.

Future Work:

The challenges and next steps required to complete the fabrication of a fully functioning MoS2 Interdigitated Antenna are:

1- Determine reason behind samples 'burning' after SiO_2 deposition.

2- Compare and optimize the measured photocurrent with that reported in literature.

3-Test for and optimize terahertz emission.

Terahertz Detection

In parallel, we designed and built a Terahertz spectrometer to study THz emission (Fig. 3 & 4)

- An 800nm, 45fs beam (from a 4MHz, 650nJ oscillator) is divided into two
  - a generation beam: to photoexcite the antennas
  - a gating beam: to measure emitted THz using a ZnTe crystal
- Two parabolic mirrors collimate and refocus the emitted THz radiation

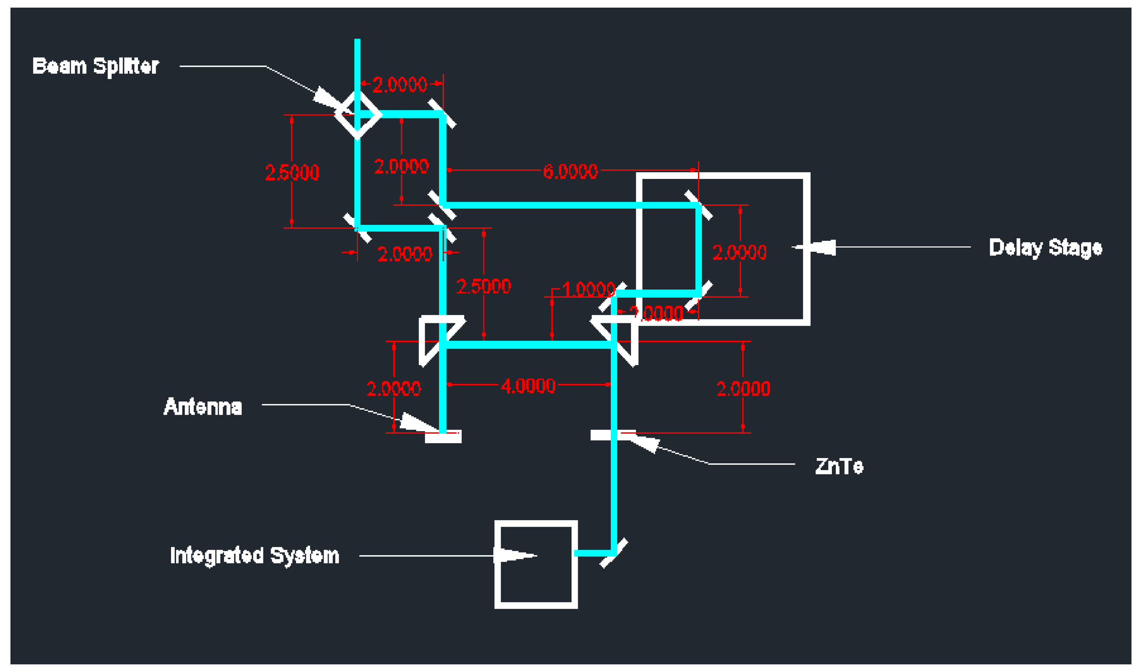

Figure 3: Preliminary drawing for the set-up.

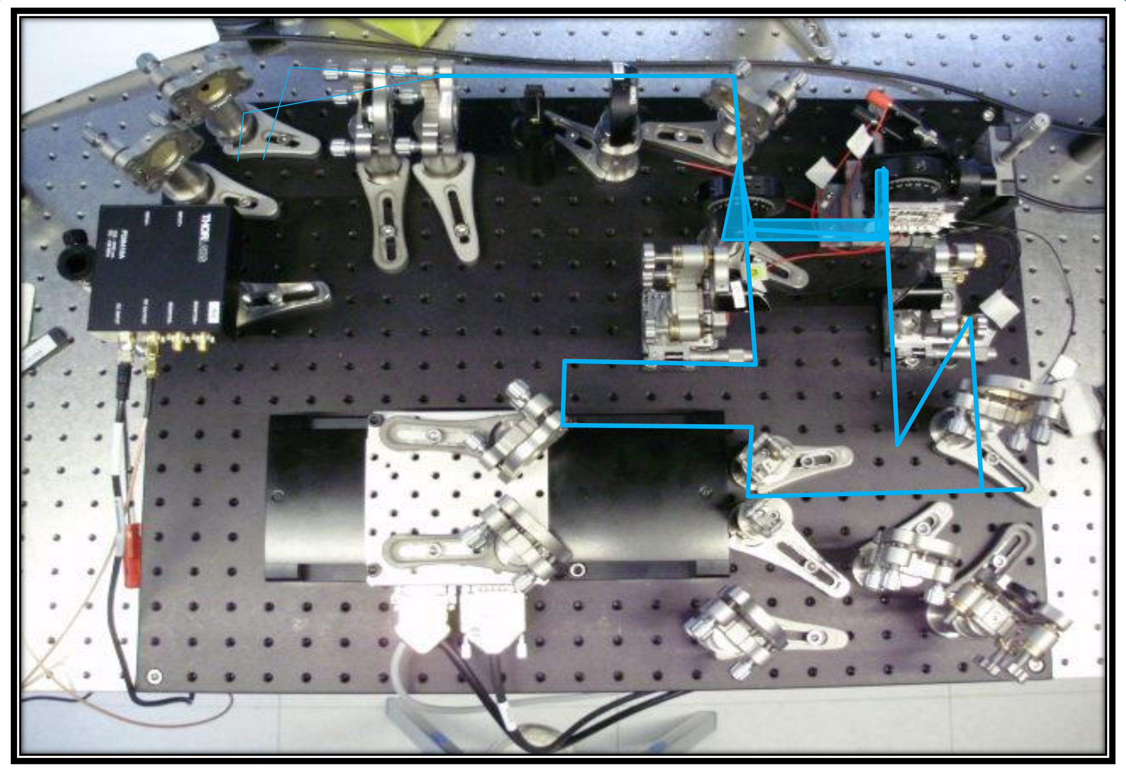

Figure 4: Final set-up: Space limitations resulted in modifications to the preliminary drawing.

Results:

Using a biased GaAs antenna as reference modulated at 10kHz and photoexcitation power of 200mW, the spectrometer was able to detect a few cycle terahertz wave form with a bandwidth of 1.5THz. Further optimization is in progress.

Future Work:

1- Improve SNR and detectable bandwidth.

2- Build a purge box to eliminate humidity in the system.

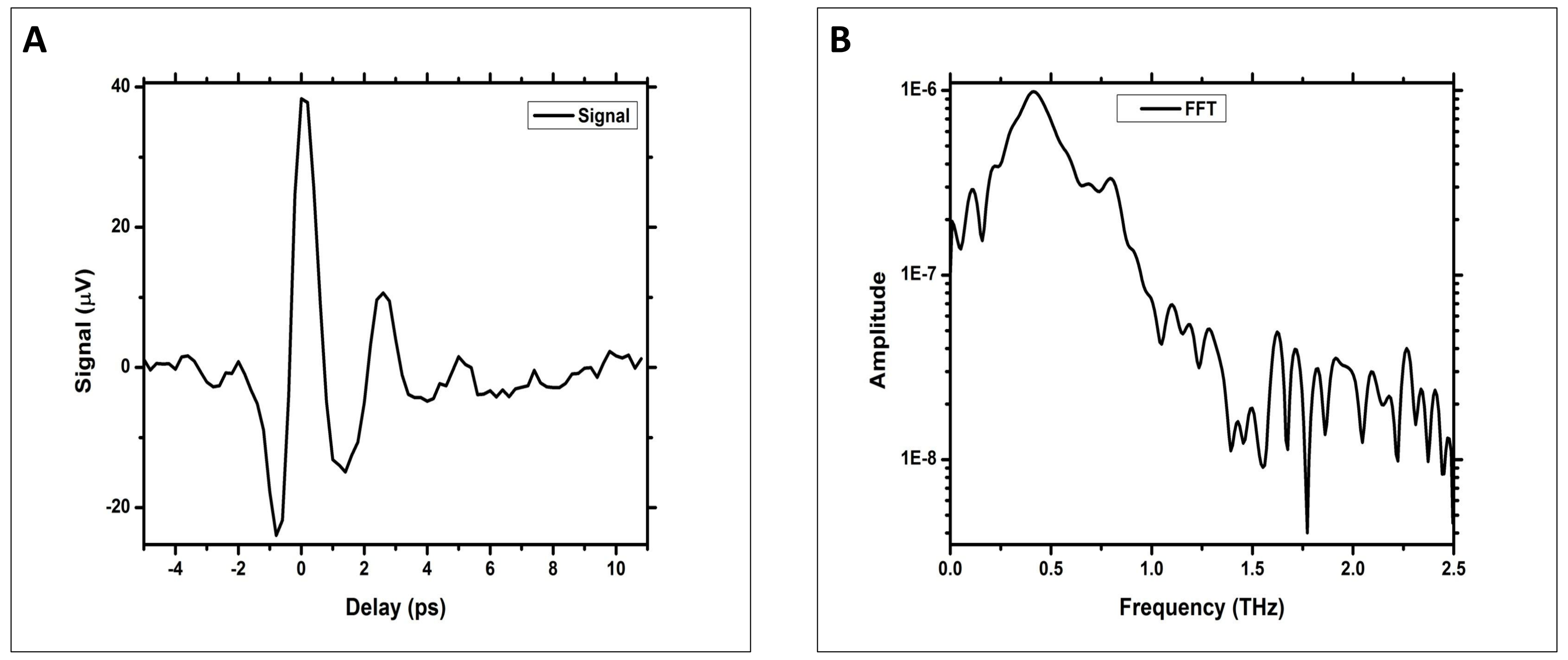

Figure 5: A) Initial waveform without purge
B)Fourier transform of the wave form.

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