# Propagation Control of Ultrashort Plasmon Wavepacket in Graphene

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Graphene plasmon polaritons in the terahertz (THz) and mid-infrared frequency range have attracted significant interest as potential next-generation information carriers due to their strong light confinement capabilities, high controllability through carrier density modulation, and low loss characteristics. However, propagation control of wavepacket, which is inevitable for plasmonic circuit operation, has not been achieved. In this work, we demonstrate on-chip generation, propagation manipulation, and time-domain detection of ultrashort plasmon wavepacket in graphene [1].

We developed a system for exciting 1-ps-wide electrical pulse and detecting it in time domain with sub-picosecond time resolution [2]. Our device consists of 8-μm-wide and 26-μm-long graphene encapsulated by hBN with a Ti/Au top gate, two photo-conductive (PC) switches, and coplanar waveguides connecting them (Fig. 1a). We conducted pump-probe experiments using a pulsed femtosecond laser. Pump beam excites one PC switch to inject a THz electrical pulse into the graphene from one ohmic contact, and the probe beam excites the other PC switch to read out the waveform after it passes through the graphene.

Figures 1b and 1c show the time-domain waveform for various gate biases. At a large carrier density (top trace in Fig. 1c), the pulse duration is 1.2 ps, which is the shortest plasmon wavepacket ever created by electrical excitation. Plasmon velocity obtained from the peak time is $3.3 \times 10^6$ m/s, two orders of magnitude slower than light. The velocity can be further decreases with decreasing carrier density following $v \propto n^{1/4}$, as expected for acoustic graphene plasmons. The slower and tunable velocity is beneficial for constructing active plasmonic nano-circuits. Our platform represents a significant advance in on-chip handling of plasmonic signals, accelerating the progress of polariton studies in van der Waals heterostructures and electron quantum optics in various quantum nanocircuits.

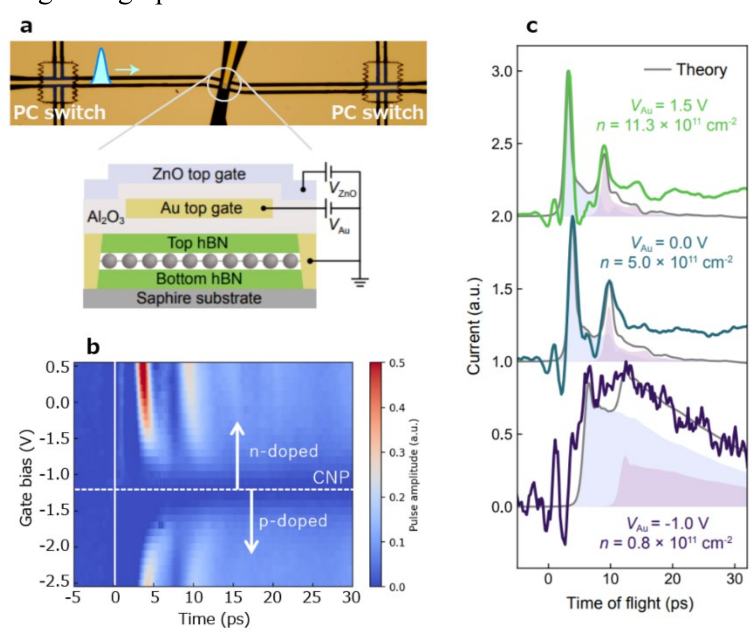


Fig. 1. **a,** (top) Microscope image of the sample. Graphene is embedded in the coplanar waveguide between the two PC switches. (bottom) Cross-sectional view of the graphene sample. **b,** Time-domain waveform of graphene plasmons for various gate biases. **c,** Experimental (colored traces) and simulated (gray traces) normalized time-domain waveforms for three gate biases. The simulation includes the initial (blue area) and the first echo (purple area) pulses.

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References

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