# Active spintronic-metasurface terahertz emitters with tunable chirality

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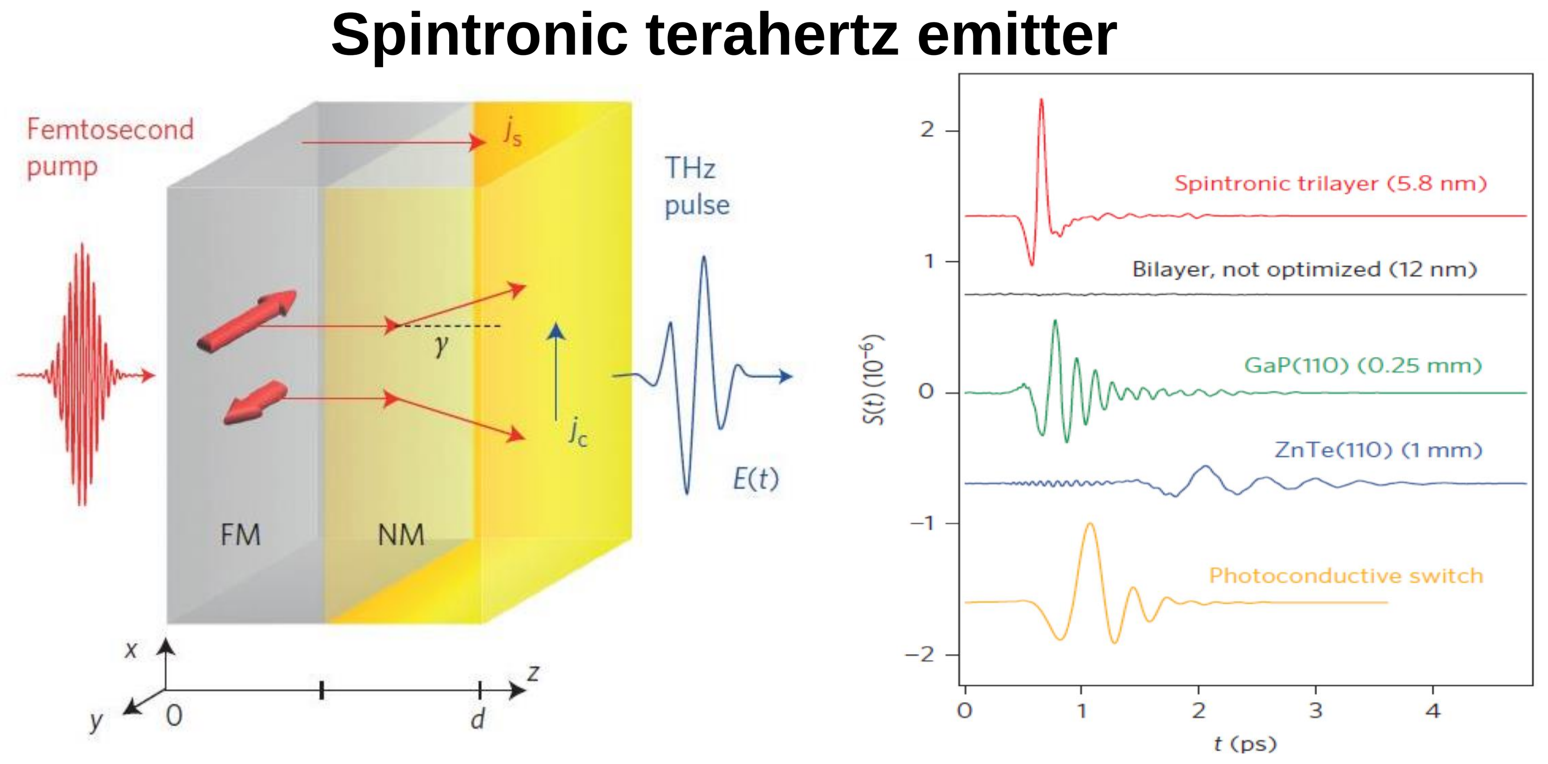
## Ⅰ Introduction

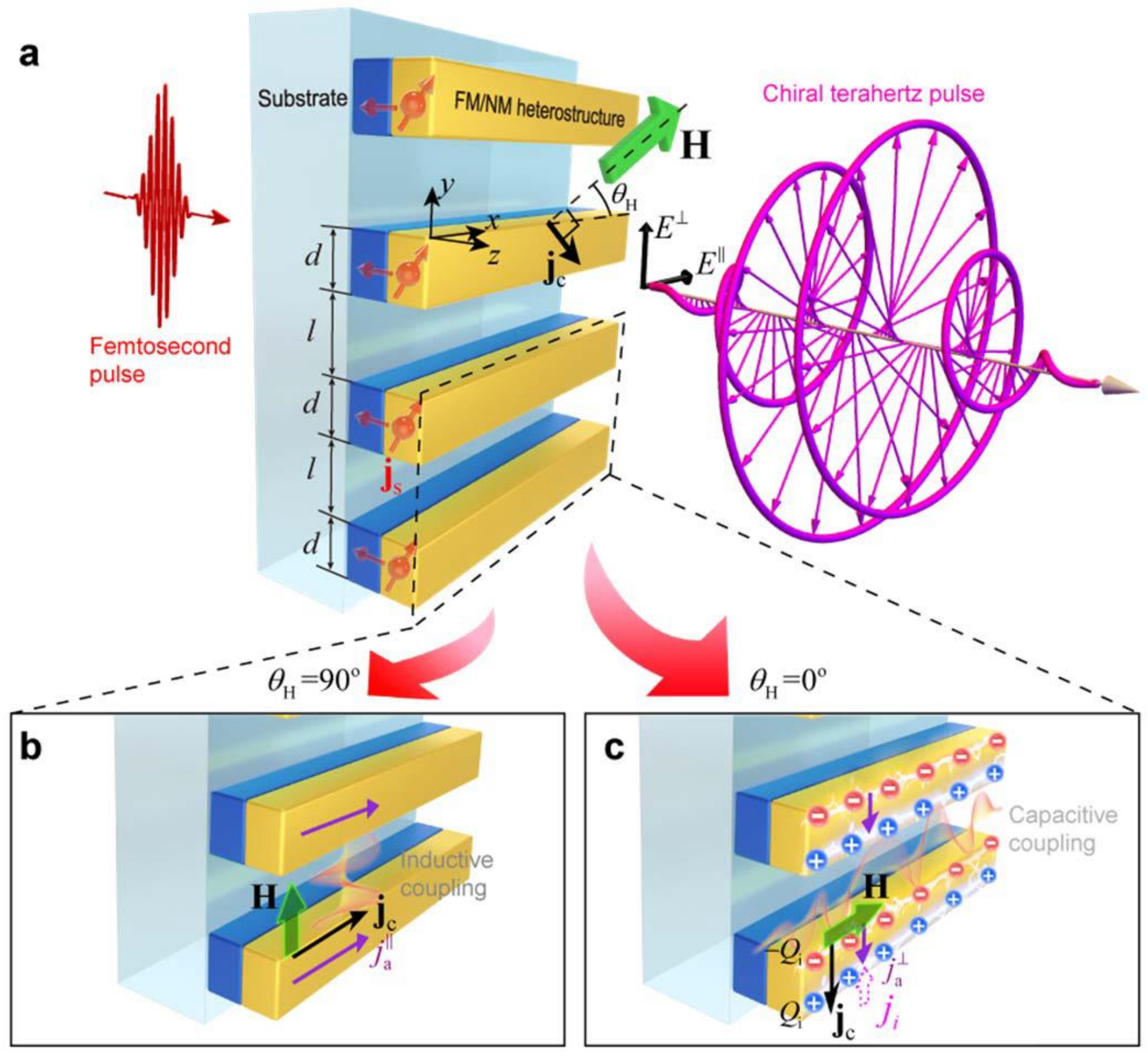
### Spintronic terahertz emitter




T.Seifert,et al. Nature Photon 10, 483 (2016).

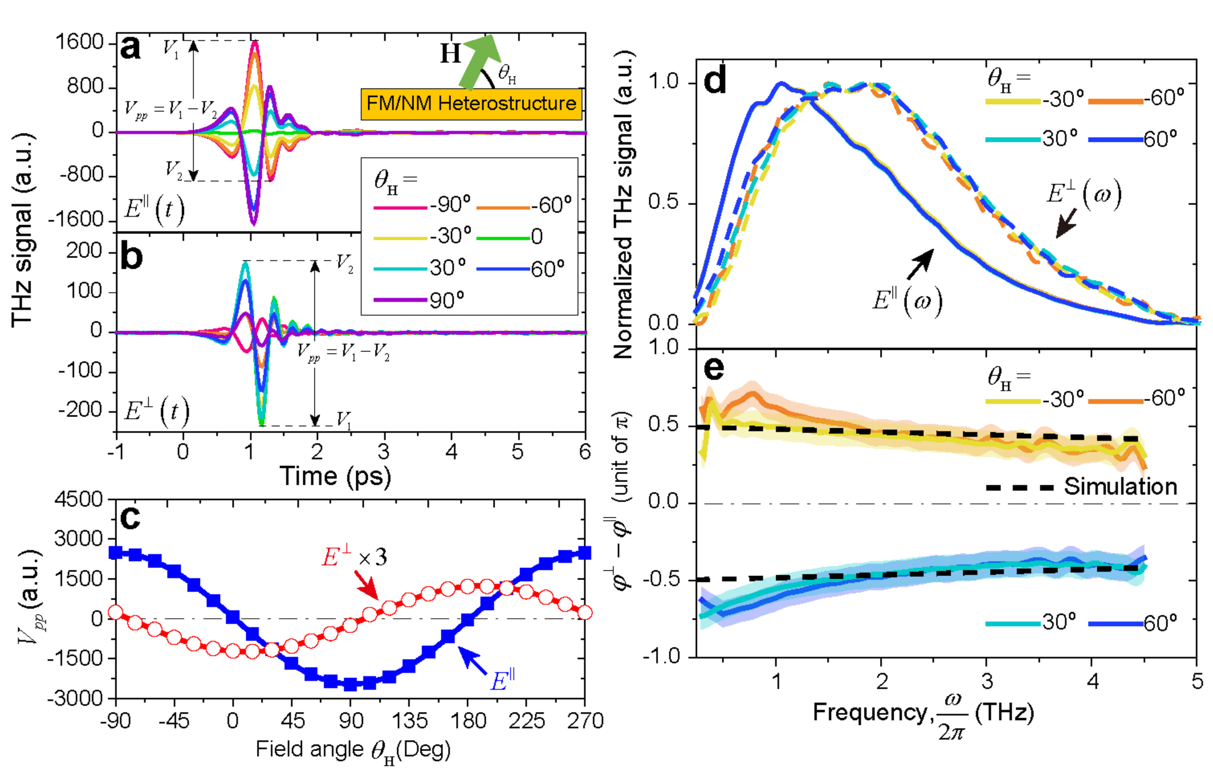
## Ⅱ Main Results

### 1. Stripe-patterned spintronic-metasurface emitter



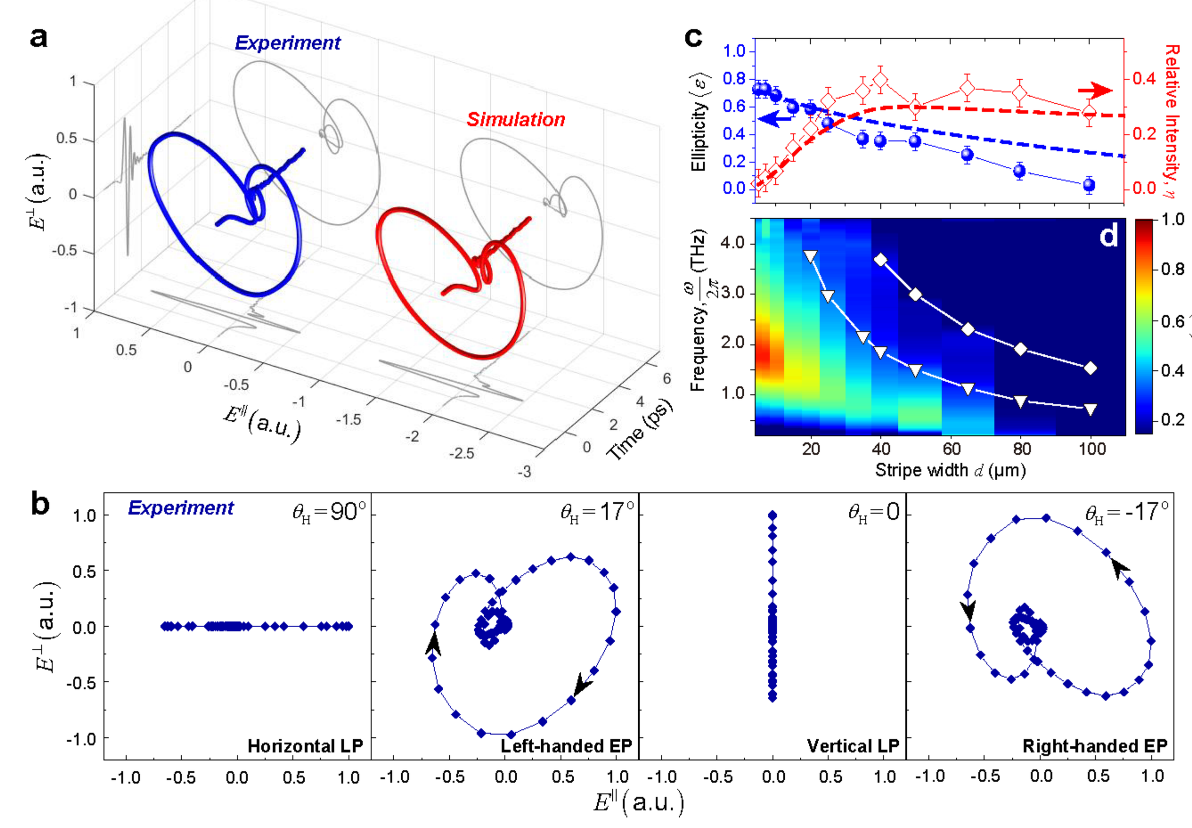

- The metasurface can influence the device functionality by inducing strong amplitude and phase modulations onto the emitted terahertz waveforms.

### 2. Modulation of terahertz spectrum and phase due to metasurface structure




- The directions parallel and perpendicular to the stripes define a set of canonical coordinates, in which the terahertz waveforms of $E^{\parallel}$ and $E^{\perp}$ are decoupled from each other and possess a broadband quarter-wave phase difference.

### 3. Generation and manipulation of chiral terahertz waveforms

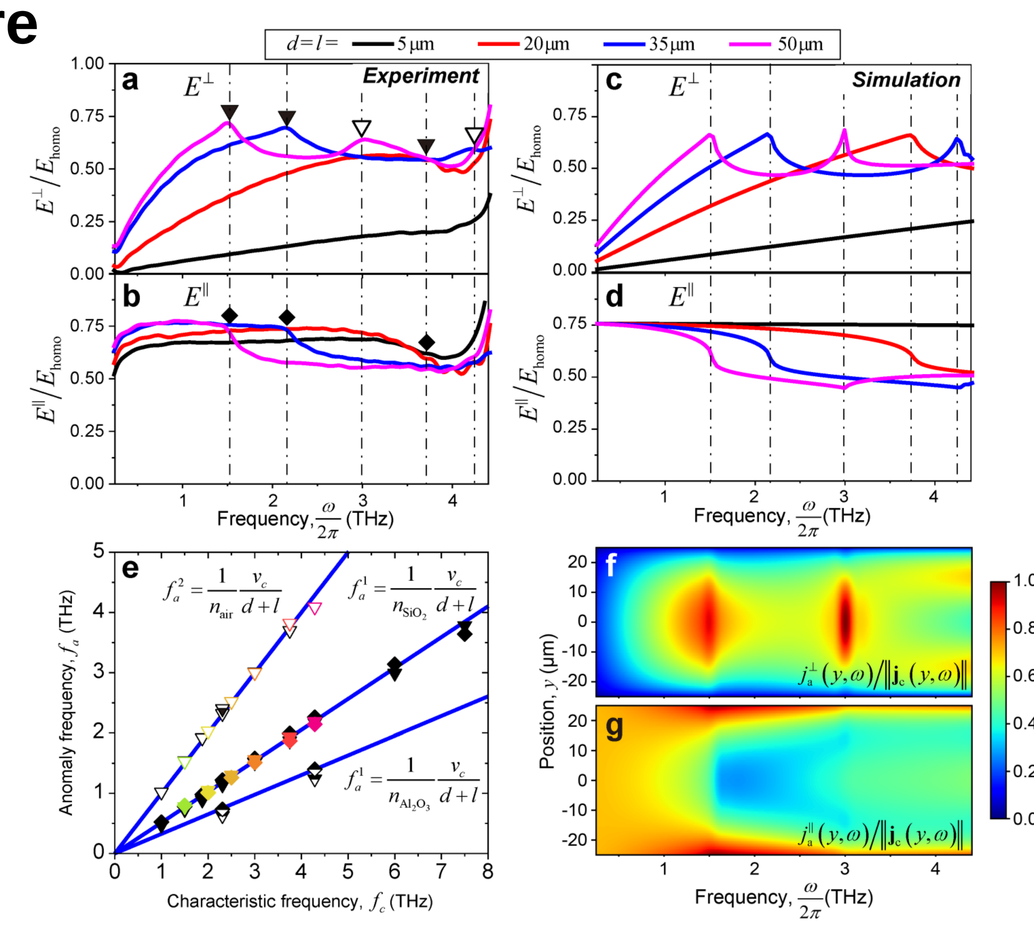



$$\langle\varepsilon\rangle=\sqrt{\frac{\int_0^\infty \varepsilon^2(\omega)\left[I^{//}(\omega)+I^{\perp}(\omega)\right]\mathrm{d}\omega}{\int_0^\infty \left[I^{//}(\omega)+I^{\perp}(\omega)\right]\mathrm{d}\omega}}$$

$$\eta=\frac{\int_0^\infty \left[I^{//}(\omega)+I^{\perp}(\omega)\right]\mathrm{d}\omega}{\int_0^\infty I_{\mathrm{homo}}(\omega)\,\mathrm{d}\omega}$$

- The ellipticity and handedness of the emitted terahertz radiation can be conveniently and continuously controlled by changing the field angle $\theta_H$ because the relative quart-wave phase difference can be well maintained in a broad bandwidth.

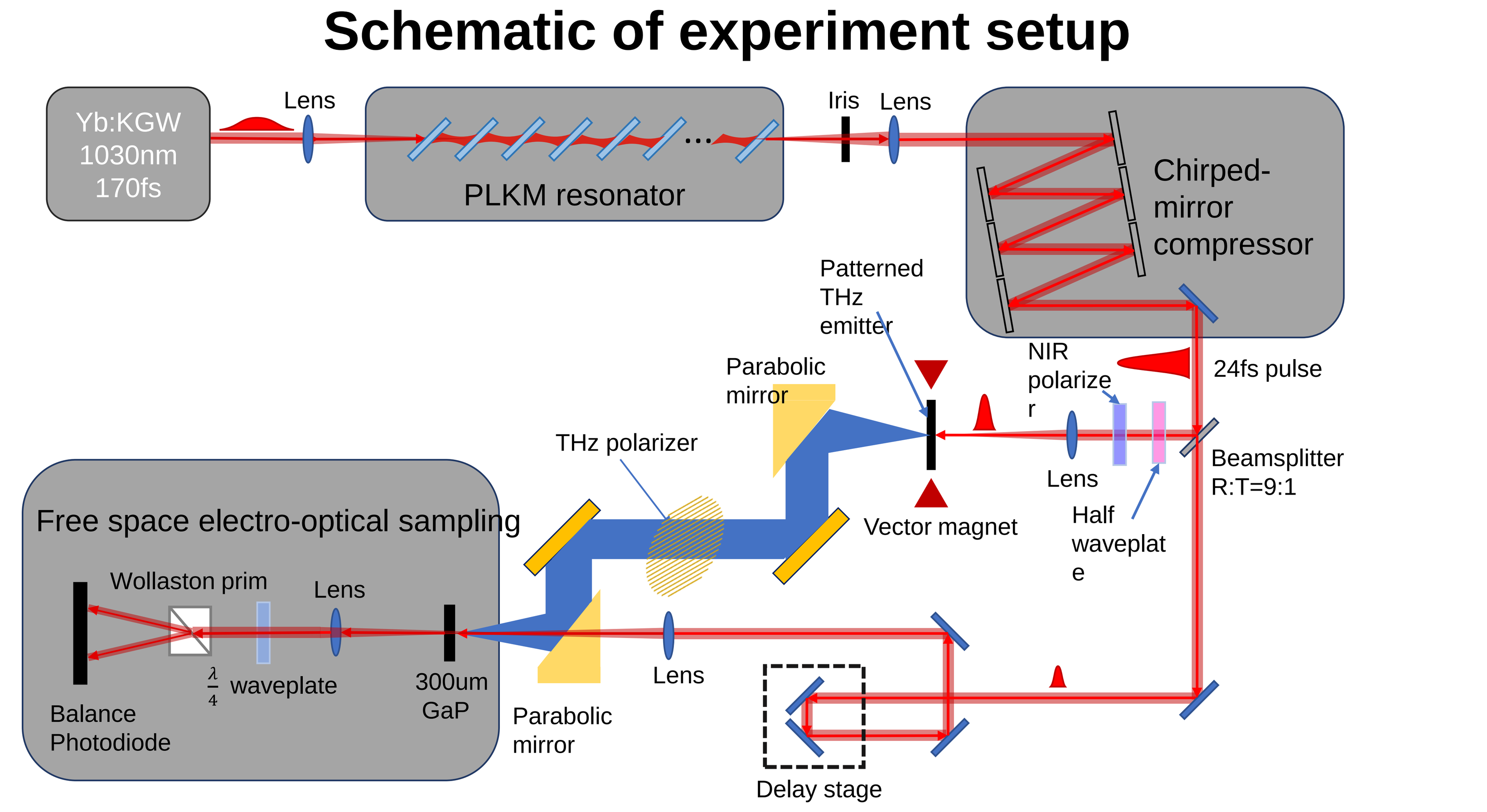
### 4. Spectral anomaly due to coupling over the metasurface structure




- This observation confirms that the spatial confinement on the laser-induced transient currents in the stripe-patterned metasurface is responsible for the observed spectral and phase modulations, as well as for the generation of chiral terahertz waveforms.

## Ⅲ Experiment Set Up

### Schematic of experiment setup




- The ultrashort laser pulses (duration ~24 fs, center wavelength 1030 nm and repetition rate 100 kHz) generated by the a compressed Yb:KGW laser amplifier are used to excite the active spintronic-metasurface device.
- The high-quality pulse compression is enabled by the solitary beam propagation in periodic layered Kerr media.
- The emitted terahertz field and its polarization state are detected by the polarization- and time-resolved terahertz spectroscopy setup based on electro-optic sampling (EOS).

## Ⅵ Conclusion

- Taking a stripe-patterned metasurface as an example of spintronic-metasurface terahertz emitter, we demonstrate the efficient generation and manipulation of broadband chiral terahertz waves. The ellipticity can reach >0.75 over a broad terahertz bandwidth (1 – 5 THz).
- Flexible control of ellipticity and helicity is also demonstrated with our systematic experiments and numerical simulations.
- We show that the terahertz polarization state is dictated by the interplay between laser-induced spintronic-origin currents and the screening charges/currents in the metasurfaces, which exhibit tailored anisotropic properties due to the “predesigned” geometric confinement effects.