Momentum Conversion Followed by Frequency Conversion in a Spatiotemporally Modulated Optical Metasurface

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When light crosses a spatial boundary between two media, its momentum changes while its frequency remains constant. In contrast, when light propagates through a medium with a time-varying dispersion relation, its frequency changes while its momentum remains unchanged. The ability to induce both conversions with the same wave pulse enables the concept of cascade frequency conversion, allowing for significant spectral transformations with minimal perturbations to the medium.

In this study, we explore this capability using a quasi-guided mode in a GaAs metasurface and a two-pump, single-probe experimental setup. By modulating the metasurface with two pump pulses separated in both space and time, we create spatial and temporal interfaces between pumped and unpumped regions. This arrangement enables a two-step process: first, momentum conversion at the spatial interface, followed by frequency conversion at the temporal interface. Our results demonstrate new opportunities for ultrafast control of light's spectrum and propagation direction using optical metasurfaces.