Dielectric Screening in Floquet-Volkov Dressing of Semiconductors

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Light impinging a surface experiences partial reflection and transmission described by the Fresnel equations, which depend on the dielectric properties of matter at the interface. In the case of a time-periodic photonic perturbation reaching the surface of a solid, typically an infrared laser beam, the transmitted part is known to dress Bloch electrons inside the material, giving rise to Floquet-Bloch states whose properties can be tuned by controlling the characteristics of this driving beam. Those states can be probed using an additional laser beam, typically in the extreme ultraviolet range at the CELIA laboratory, using time- and angle-resolved photoemission spectroscopy (TrARPES), based on the photoelectric effect. For example, it has been recently demonstrated that below-band-gap periodic driving of semiconducting transition metal dichalcogenides with circularly polarized light enables valley-selective control of Floquet-Bloch states [1]. In such photoemission experiments however, electromagnetic dressing can also occur for the quasi-free electrons outside the material, giving rise to the competing contribution of so-called Volkov states. In certain cases, most notably in metallic systems, strong surface screening reduces the penetration of the driving electromagnetic field into the solid, resulting in Volkov contributions that dominate over Floquet ones [2]. These observations underscore the importance of carefully accounting for the material's dielectric response when analyzing photoemission experiments.

In this work, we systematically investigate the influence of materials' dielectric properties on Floquet-Volkov dressing of semiconductors, focusing on layered van der Waals materials GeS, SnS, and 2H-WSe_2. First, by combining a simple model based on Fresnel equations with an electron-scattering description of Volkov amplitudes, we use polarization-dependent Volkov sideband intensities to extract a lower bound for the real part of the materials' dielectric function. The extracted values typically lie between the reported dielectric constants for monolayer and bulk crystals. Furthermore, we demonstrate that increasing the pump fluence enables the generation of high-order Volkov replicas, which exhibit clear signatures of nonlinear light–matter interactions in their temporal profiles, polarization dependence, and angular distributions. Finally, we show that for our experimental geometry, the quasi-transparent nature of semiconductors in the below-band-gap driving regime allows the optical pump to propagate within the sample and undergo multiple total internal reflections, producing a series of temporally delayed Volkov replicas in pump–probe measurements via electromagnetic dressing of photoelectrons by the evanescent field associated with total internal reflections. Together, these studies uncover unexplored aspects of Floquet–Volkov dressing in solids, highlighting the central role of dielectric screening of the driving field.

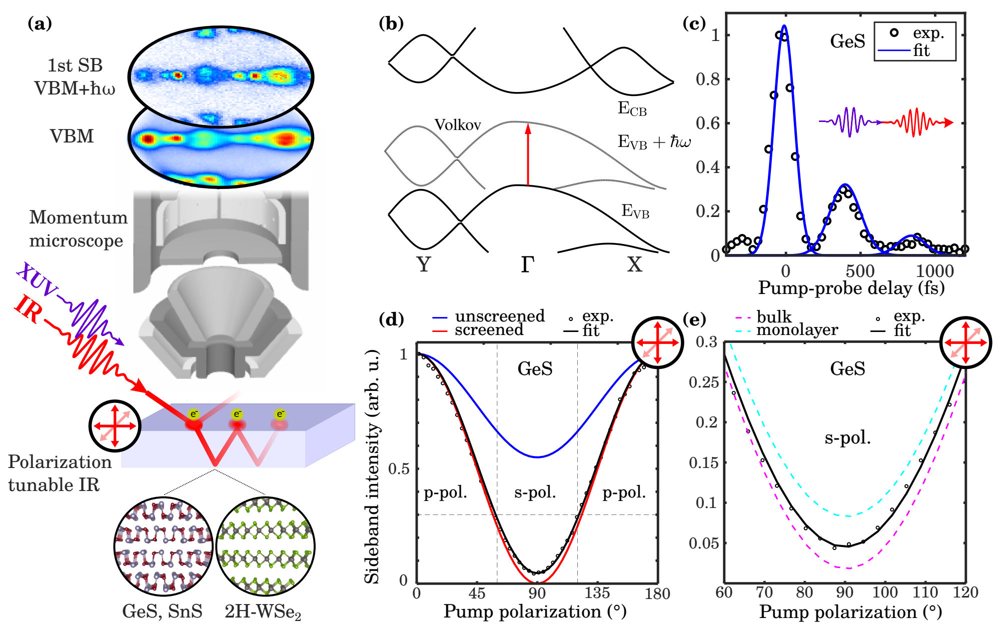

FIG. 1. **(a)** Schematic of the time- and polarization-resolved extreme ultraviolet momentum microscopy experiment. **(b)** Schematic of Volkov dressing of GeS upon below-bandgap pumping. **(c)** Multiple Volkov sidebands in the time-domain and associated fit using the Fresnel-Volkov model. **(d)-(e)** IR polarization-dependent Volkov intensities and associated fit using the Fresnel-Volkov model, allowing to extract the real part of the dielectric function, here exemplified for GeS.

[1] Fragkos et al. *Nature Communications*, 16, 5799 (2025).
[2] Keunecke et al. *Physical Review B*, 102, 161403 (2020).