

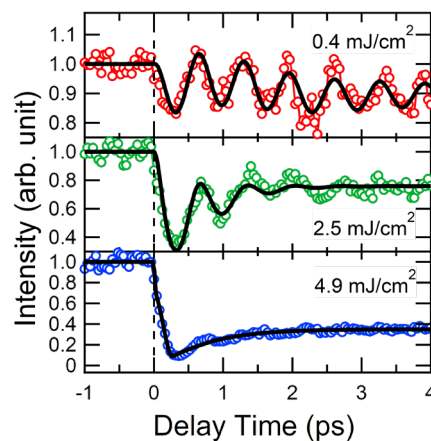
# Time-resolved ARPES and XRD study of charge-density-wave materials

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Collective excitations ubiquitously emerge as a consequence of spontaneous symmetry breaking. A prototypical example in solid-state systems is the charge density wave (CDW), in which the formation of a periodically modulated electronic state gives rise to characteristic amplitude and phase modes across the CDW phase transition. These collective modes, reflecting fluctuations of the order parameter, provide direct insight into the underlying symmetry and many-body interactions. Owing to their fundamental importance and rich dynamics, CDW amplitude and phase excitations have attracted sustained and widespread interest for several decades.

In this presentation, I will report on our recent investigations of the ultrafast dynamics in CDW materials using time-resolved X-ray diffraction (tr-XRD) and angle-resolved photoemission spectroscopy (tr-ARPES). We focus first on  $VTe_2$ , which exhibits a CDW phase below 480 K accompanied by a structural transition from the trimerized  $1T$  phase to a monoclinic  $1T''$  phase. Figure 1 shows the fluence-dependent tr-XRD results for  $2/3\ 0\ 11/3$  superlattice reflection. At low excitation fluence ( $0.4\ \text{mJ}/\text{cm}^2$ ), coherent oscillations at 1.5 THz are clearly observed, which we identify as the CDW amplitude mode. In contrast, at high fluence ( $4.9\ \text{mJ}/\text{cm}^2$ ), the oscillatory component is strongly suppressed and accompanied by a relatively slow recovery, indicative of photoinduced CDW melting dynamics. Furthermore, I will present complementary results on  $TaTe_2$  and  $4Hb\text{-}TaS_2$ , which exhibit distinct nonequilibrium behaviors, underscoring the material-dependent pathways of ultrafast CDW dynamics.



**FIGURE 1.** Summary of the fluence-dependent dynamics of the  $2/3\ 0\ 11/3$  superlattice reflection.

## REFERENCES

1. T. Suzuki *et al.*, *Ultrafast control of the crystal structure in a topological charge-density-wave material*, Phys. Rev. B, **108**, 184305 (2023).