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Femtosecond-laser induced ultrafast melting in Si and the possibility to control it

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Femtosecond-laser pulses can induce structural phenomena like solid-to-solid phase transitions and ultrafast melting in crystalline structures. The main reason for the appearance of such effects is the ultrafast modification of the bonding properties in the induced nonthermal state consisting of extremely hot electrons and nearly unaffected cold ions. Although melting is a stochastic process in thermodynamical equilibrium, we show that in the laser excited nonthermal case some coherences are preserved or created. Moreover, by performing ab initio molecular dynamics simulations of the excitation of silicon by a series of laser pulses, we demonstrate that it is possible to control nonthermal melting by light. Analyzing the energy flow in quasimomentum space, we found that the ultrafast disordering atomic motion can be stopped and redirected depending on the delay between the pulses. Essential for the controlling mechanism is the appearance of an intermediate state in the excitation process that shows a laser-induced coherent motion of the atoms. The appearing oscillation follows directly the bond softening of the
material and can be connected to laser-changed thermal phonon frequencies.

Primary author: ZIER, Tobias (University of California, Merced, United States)

Presenter: ZIER, Tobias (University of California, Merced, United States)

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