Ultrafast Anisotropic Spin-Lasers

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The modulation bandwidth of conventional intensity-modulated semiconductor lasers is ultimately limited by the coupled dynamics of carriers and photons in their cavities. Spin lasers can break through this barrier by harnessing the coupled dynamics of carrier spin and photon spin in microcavities with engineered anisotropy. In such devices, controlling the phase and amplitude anisotropies is equivalent to controlling the resonance frequency and the damping of the coupled spin system, enabling ultrafast modulation of light polarization rather than its intensity. Spin-polarized vertical-cavity surface-emitting lasers (spin-VCSELs) have already demonstrated polarization modulation bandwidths beyond 200 GHz and theoretical models already predict a push into the THz range. This exceptional speed, a high energy efficiency, and their temperature stability make anisotropic spin lasers promising devices for a wide range of applications, including next-generation optical links for ultrafast optical communications, neuromorphic computing, chaos-based random bit generation, and compact microwave or THz sources. However, these applications require fully integrated and electrically controlled devices, the development of which is highly challenging and the target of numerous current research efforts worldwide.

In this talk, I will present promising concepts for electrical injection and electrical modulation of spin and discuss the potential of combining ultrafast spin dynamics with micro- or nanolaser integration.