Engineering Active Photonic Devices and Networks

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Nano-patterned photonic materials have revolutionized the way light is generated and transported on chip-scale structures. Incorporating active components opens up a different design dimension for integrated optical circuits, enabling entirely new functionalities for transport and generation of light. I will discuss our theoretical efforts in this direction leveraging spatial and temporal modulation of the real and imaginary parts of the refractive index of photonic materials. The dynamical evolution of these systems are generally described by non-Hermitian operators and the spectral properties of such operators permit a much richer range of dynamical behavior than those described by Hermitian or normal operators. First I will focus on our work on large-area microlasers where we have shown how spatially selective pumping can control the emission directionality, frequency and threshold. Next, I will discuss an interesting dynamical regime of a coupled laser system, related to a special degeneracy ("exceptional point") of the associated non-Hermitian operator, that can be accessed via differential pumping of individual elements. This proposal was recently realized with THz quantum cascade lasers. Finally, I will discuss the design of a network of electromagnetic oscillators for on-chip non-reciprocal routing of light. By virtue of the reliance of this scheme on spatial and temporal modulation of network parameters, we are able to demonstrate general design principles for reconfigurable, point-to-point transport of light on the network that is immune to backscattering.