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Real-time twisting on a chip

Two-dimensional materials (2DM) and their heterostructures offer tunable electrical and optical properties, primarily modifiable through electrostatic gating and twisting. While electrostatic gating is a well-established method for manipulating 2DM, achieving real-time control over interfacial properties remains a frontier in exploring 2DM physics and advanced quantum device technology. Current methods, often reliant on scanning microscopes, are limited in their application scope, lacking the accessibility and scalability of electrostatic gating at the device level. In this work, we introduce an on-chip platform for 2DM with in situ adjustable interfacial properties, employing a microelectromechanical system (MEMS). This platform comprises compact and cost-effective devices capable of precise voltage-controlled manipulation of 2DM, including approaching, twisting, and pressurizing actions. We demonstrate this technology by creating synthetic topological singularities, such as half-skyrmions or merons, in the nonlinear optical susceptibility of twisted hexagonal boron nitride (h-BN). A key application of this technology is the development of integrated light sources with real-time and wide-range tunable polarization. Additionally, we envision a quantum analog capable of generating entangled photon pairs with adjustable entanglement properties. Our work extends the capabilities of existing technologies in manipulating low-dimensional quantum materials and paves the way for novel hybrid 2D-3D devices, with promising implications in condensed-matter physics, quantum optics, and related fields.

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