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Field Effect Optoelectronic Modulation of Quantum-Confined Carriers in Black Phosphorus WILLIAM WHITNEY, MICHELLE SHERROTT, DEEP JARIWALA, WEI-HSIANG LIN, California Institute of Technology, HANS BECHTEL, Lawrence Berkeley National Laboratory, GEORGE ROSSMAN, HARRY ATWATER, California Institute of Technology — Black phosphorus has attracted considerable interest as a layered, two-dimensional semiconductor with high mobility, a narrow, direct band gap, and heavily anisotropic electronic properties. Thin flakes form natural quantum wells, and theory predicts black phosphorus to show technologically promising electro-optical effects and an oscillatory optical conductivity due to its quantized intersubband transitions. However, much of this novel behavior remains to be experimentally observed - in part due to the difficulty of infrared measurements on small, micron-scale exfoliated samples. We report here the first investigation of the infrared response of black phosphorus in which the Fermi level is varied by electrostatic gating, enabled by use of the high-brightness infrared beam at the Advanced Light Source synchrotron. These measurements reveal new physics, including strong optoelectronic modulation driven by ambipolar Burstein-Moss and quantum-confined Franz-Keldysh effects under high fields. The oscillatory optical conductivity is modified by Pauli-blocking of interband transitions as the Fermi level shifts, and additional modulation is seen that we attribute to modification of selection rules and carrier wavefunctions by the predicted Franz-Keldysh behavior.

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