Electro-optic interface for ultrasensitive intra-cavity electric field sensing

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Abstract— **We demonstrate a fibre-coupled, fully monolithic electro-optic coherent interface on the silicon-photonics platform that senses terahertz electric fields with sub-cycle resolution by means of nonlinear coupling with photons at telecom frequencies. A strong confinement of the terahertz field to a cavity mode enables a coupling strength to sense fields as low as 20 V/m. We discuss the opportunities such platforms provide for sensing of cavity-confined terahertz states at the quantum limit.**

I. INTRODUCTION

ULTRAFAST oscillating terahertz waves have enabled several breakthroughs in telecommunication [1], quantum electrodynamics [2], or nanoscopy [3,4]. So far, most applications are classical, and, as such, do not operate in the quantum regime. Recently, sensing of terahertz fields has become accessible at the quantum limit by electro-optic sampling [3] in free-space. Therefore detection of cavity-confined quantum states at terahertz frequencies has been elusive up to date. A cavity confinement not only provides the possibility for quantum engineering but can also increase the sensitivity of electro-optic detectors to sense quantum fields with better signal-to-noise ratio. We show that gold bow-tie antennas as shown in Fig. 1a can leverage on extreme field confinement to provide record-high sensitivity by co-integration with organic electro-optic molecules on a silicon-based chip. Such molecules have a demonstrated bandwidth of 2.5 THz [5,6] and a high nonlinear coefficients (r_{33} > 200 *pm/V*). An interferometer formed by silicon waveguides is monolithically integrated with the antenna and transforms the intracavity terahertz field into an intensity modulation of the probe pulses.

II. RESULTS

We characterize the sensitivity of our detectors by shining a broadband coherent terahertz transient onto the chip, as shown in Fig. 1b. From the broadband transient, only frequency components at the resonance frequency of the antenna couple to the antenna gap and are sensed by a probe pulse in the telecom with sub-cycle resolution, as shown in Fig. 1c.

We present the quantum description of the physics of our device. From sensing experiments, we determine the sensitivity and compare it with state-of-the art results from quantum sensing experiments of terahertz fields [7]. We discuss how the standard quantum limit might impact the detection of free-running terahertz waves such as vacuum field fluctuations or thermal fields by electro-optic correlation measurements in these devices.

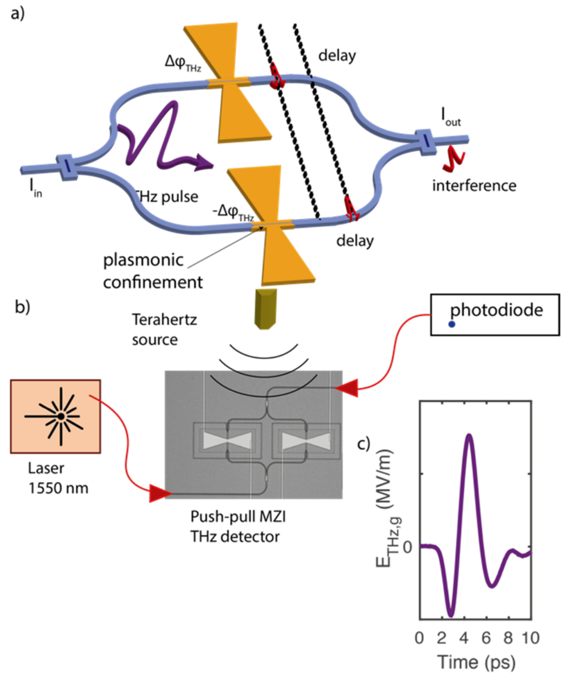

Fig. 1. A. Layout of the detector. B. Measurement scheme. C. Measured transient with an antenna resonance centered around 220 GHz.

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