Detector of Topologically Structured Light

L. Vignjevic[1], **E. Plum**[1], **N. Papasimakis**[1], **N. I. Zheludev**[1,2]

[1] *Optoelectronics Research Centre, University of Southampton, SO17 1BJ, UK*

[2] *Texas A&M University, Institute for Advanced Study, USA*

We report an absorption-based detector selective to the topological spatial structure of light, where a radially polarized beam or toroidal electromagnetic pulse is fully absorbed, while plane waves of any polarization are rejected.

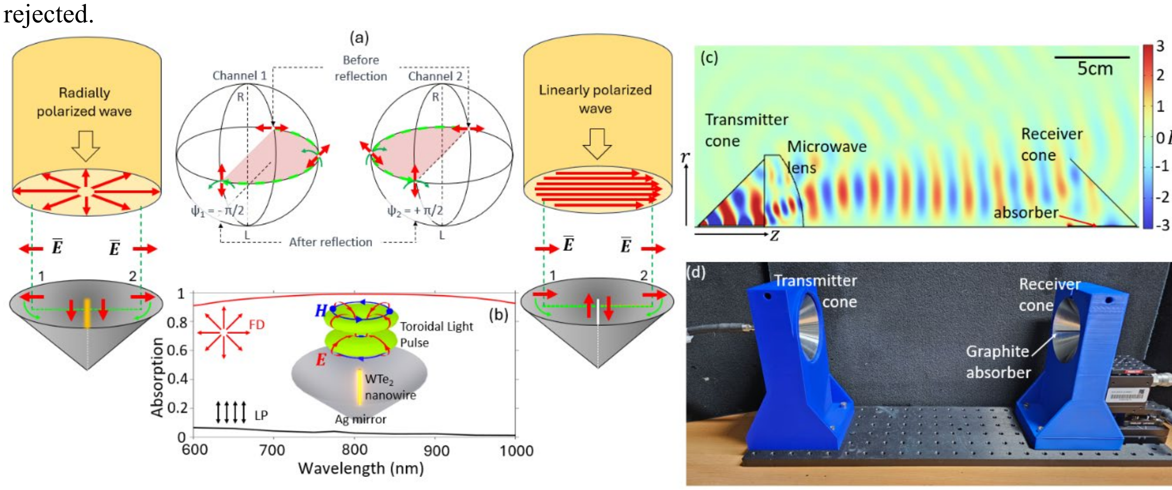

Fig. 1. (a) Geometrical phase effects of radially and homogeneously linearly polarized waves reflected on a conical mirror. The π geometrical phase difference in channels 1&2 results in a cylindrical standing wave around the axis of the mirror. For azimuthally and linearly polarized light, there will be a standing wave node on the mirror axis, meaning any absorber placed there will not interact with the light and the device will fully reflect the incident beam. For incident radially polarized light, the imparted geometric phase results in a standing wave antinode and strong absorption. (b) Absorption of flying doughnut (red, FD) and linearly polarized (black, LP) pulses, with a schematic of the FD pulse inset. (c-d) Microwave implementation of the absorber device: Finite element simulations (c) and experimental setup (d).

The principle of operation of the topological light detector is illustrated in Fig. 1a. It comprises a conical mirror coaxial with the incident propagating beam or pulse. Upon reflection on the conical mirror, the incident beam accumulates a geometrical Pancharatnam-Berry phase and is converted into a standing wave. If a “nanowire” absorber is placed along the axis of the cone, radially polarized light creates an antinode of the standing wave at the absorber and nearly perfect dissipation of light’s energy can be achieved regardless of the wavelength. This is the 1D analogue to the coherent perfect absorption process in thin film absorbers [1]. Conversely, a homogeneous plane wave of any polarization state forms a field antinode at the absorber and is reflected with no loss of energy. We developed an analytical description of the absorber based on Mie theory, which accurately predicts the material properties necessary to achieve perfect absorption.

We consider a detector of Flying Doughnuts (FDs), toroidal few-cycle pulses [2] with a polarization singularity (see inset to Fig. 1b), comprising a WTe_2 nanowire along the axis of an Ag conical mirror. Such a device absorbs FD pulses across the vis/near-IR with absorption exceeding 90%, while it almost fully rejects linearly polarized pulses (Fig. 1b). A microwave implementation of the topological light detector is presented in Figs. 1c-d.

In conclusion, we introduce an absorber selective to the topology of incident, which will be of interest for applications in energy harvesting, detection, filtering, and telecommunication applications. We expect to report experimental results at the time of the conference.

References:

[1] J. Zhang, K. F. MacDonald, and N. I. Zheludev. “Controlling light-with-light without nonlinearity”. *Light Sci. Appl.* **1**, e18 (2012)

[2] A. Zdagkas, Y. Shen, C. McDonnell, J. Deng, G. Li, T. Ellenbogen, N. Papasimakis, and N. I. Zheludev, “Observation of toroidal pulses of light,” Nature Photon. **16**, 523-528 (2022).