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Opportunity Title: Impact of Twisted, Bent Fiber on Orbital Angular Momentum Light Wave Propagation
Opportunity Reference Code: IC-18-26

Organization Office of the Director of National Intelligence (ODNI)

Reference Code IC-18-26

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Additional information about the IC Postdoctoral Research Fellowship Program is available on the program website located at: https://orau.org/icpostdoc/.

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Application Deadline 3/12/2018 11:58:00 PM Eastern Time Zone

Description **Research Topic Description, including Problem Statement:**

- With the recognition of the property of orbital angular momentum (OAM) in a light beam and its potential for exploitation for practical uses, the interest in the study of OAM modes of a beam of light in free space or in a dielectric waveguide such as a multimode fiber has increased dramatically [1,2]. One of the possible applications is in the commercial field of telecommunications where it can provide multifold increase in traffic flow within a fiber. The idea is to stack traffic into different OAM modes which is possible due to their orthogonality. Consequently, a number of experimental studies are being conducted to prove its efficacy. The biggest drawback is the mixing of these modes due to fiber imperfections like ellipticity (i.e., deviations from perfect roundedness) and unavoidable bends in fiber which can be sporadic and constitute the biggest source of mode-mixing.
- The impact of bending a fiber on OAM modes propagating down the fiber has been studied in the past in a laboratory environment via the turning of paddles of a polarization controller (POLCON). While these effects have been well documented [3], e.g., OAM mode of parameter "*l*" changing from -1 to +1 or vice versa via the manipulation of the paddles of the POLCON, no detailed theoretical models to quantify these effects have been presented to date.

Example Approaches:

The common approach to deal with this problem is to use the weakly guiding approximation and the model of bent fiber as given in [4]. The wave form in the outer part of the bent fiber travels faster than in the inner part leading effectively to wave propagation in a straight fiber with a modified refractive index which varies radially and azimuthally. This deviation in the refractive index can then be treated as perturbation [5] to solve for mode-mixing. This model is limited to bends in the same plane as the straight sections of the fiber and thus does not encompass the twisting of the fiber suffered as the paddles of the POLCON are rotated. Additional approaches could include research to develop:

- A detailed theoretical model of a straight fiber bending into a circular loop of a given radius and tilted at a fixed angle in space would allow prediction of the impact of this configuration on an OAM mode of a given OAM value of *l* corresponding to propagation in a straight fiber as a function of the tilt angle measured from the vertical axis of the original loop. The tilt angle in general is specified by a polar angle and an azimuthal angle.
- Extension of the model to multiple circular loops with the same center.
- Extension of the model to a succession of connected loops having a different center as in a POLCON.
- Extension of the model to an elliptical loop.

The above sub-statements of the problem are a suggestion and serve as a guide. It is well-known that input polarization in a single mode fiber (*l* =0) changes in a bent fiber, but this is generally ascribed to the stress and strain experienced by the fiber. Polarization of a light beam is in general a linear superposition of left-circular polarization (S=+1) and right-circular polarization (S=-1), where S refers to the spin angular momentum per photon of the beam in units of h/(2π). Recent experiments have shown that for high *l* values (in one example, *l*=18 in a multimode fiber), the input polarization (left or right circular) remains unaltered when the POLCON paddles are moved. Is it possible that the current thinking about the cause of the polarization change attributed to stress and strain is not correct and perhaps the developed model can explain this phenomenon? Note that in the weakly guiding approximation, the total angular momentum J separates into its two components, *l* and S, facilitating easier analyses.

References:

- L. Allen, et al., “Orbital Angular Momentum of Light and the Transformation of Laguerre-Gaussian Laser Modes”, Phys. Rev. A 45, 8185 (1992).
- Alan E. Willner, “Twisted Light Could Dramatically Boost Data Rates,” IEEE Spectrum, August 2016.
- N. Bozinovic, et al., “Control of Orbital Angular Momentum of Light with Optical Fibers”, Optics Lett., 37, p.2451 (2012).

- Allan W. Snyder and John D. Love, “Optical Waveguide Theory”, Chapman and Hall (1983).
- S.J. Garth, “Modes on a Bent Optical Fiber”, Proc. IEE, 134, p. 221 (1987).

Qualifications

Postdoc Eligibility

- U.S. citizens only
- Ph.D. in a relevant field must be completed before beginning the appointment and within five years of the application deadline
- Proposal must be associated with an accredited U.S. university, college, or U.S. government laboratory
- Eligible candidates may only receive one award from the IC Postdoctoral Research Fellowship Program.

Research Advisor Eligibility

- Must be an employee of an accredited U.S. university, college or U.S. government laboratory
- Are not required to be U.S. citizens

Eligibility Requirements

- **Citizenship:** U.S. Citizen Only
- **Degree:** Doctoral Degree.
- **Discipline(s):**
  - **Chemistry and Materials Sciences** (12)
  - **Communications and Graphics Design** (6)
  - **Computer, Information, and Data Sciences** (16)
  - **Earth and Geosciences** (21)
  - **Engineering** (27)
  - **Environmental and Marine Sciences** (14)
  - **Life Health and Medical Sciences** (45)
  - **Mathematics and Statistics** (10)
  - **Other Non-Science & Engineering** (5)
  - **Physics** (16)
  - **Science & Engineering-related** (1)
  - **Social and Behavioral Sciences** (28)