# Atmospheric propagation experiment of Long Range Non-diffracting Beam using an annular-beam infrared laser

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**Abstract**

We conducted a propagation experiment of Long Range Non-diffracting Beam (LRNB) using an annular-beam infrared laser in a distance of approximately 660 m. Compared with a conventional focused beam, the LRNB showed an appreciable reduction of turbulence-induced fluctuation.

**Introduction**

Long Range Non-diffracting Beam (LRNB) was for the first time reported by Aruga in 1997, which propagates over a long range with maintaining its narrow beam width as if it does not diffract[1), 2)]. Although its energy concentration into the beam main lobe is inferior to a focused beam[3)], LRNB possesses advantageous characteristics of being less sensitive to the atmospheric turbulence in beam propagation.

LRNB can be generated by distorting the spherical wavefront intentionally, so that optical rays emitted near the outer edges of an aperture concentrate along a propagation axis in long ranges, while the ones from inner portions do in short distances. A typical method to generate LRNB, for example, is to use a Galileo telescope consisting of a normal convex lens and a concave lens, the latter of which provides a special spherical aberration. Considering high power laser beam propagation planned in the future wherein an annular beam is likely to be generated with an unstable laser resonator, we take a different approach that combines a refractive aberrator with a Cassegrain telescope mentioned in the following section.

In the experiment reported here, we formed a LRNB to propagate over a distance of 660 m in the atmosphere that showed significantly lower fluctuation than a focused beam.

**Experimental setup**

The layout of transmitting optics for the annular LRNB is illustrated in Fig. 1. A 300-mW, horizontally-polarized, 1340-nm CW laser beam with Gaussian intensity distribution was collimated and expanded to 40 mm in diameter by a beam expander, conveyed to the LRNB waveplate. It is made of BK7 without any coating on its surfaces, and attached to a Cassegrain telescope with a magnification of 5. Passing the beam through the waveplate and the primary/secondary mirror resulted in generation of a 200-mm diameter annular LRNB.

The beam propagation experiment was conducted for one week period in mid summer of 2005. During the experiment the refractive index structure parameter ($Cn^2$) was varied in order of $10^{-15}$ ($m^{-2/3}$).

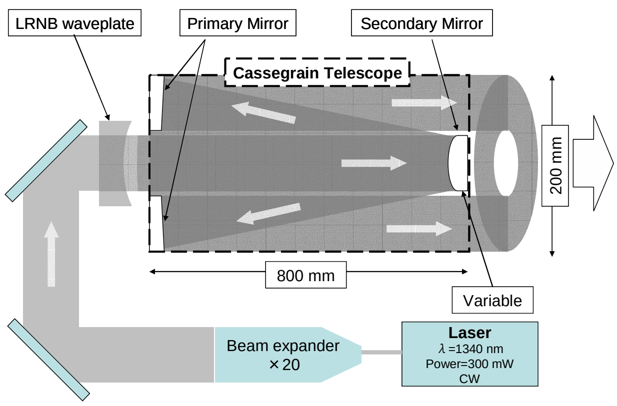


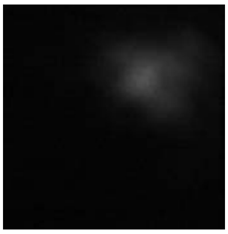

Fig. 1 Optical layout for 200-mm diameter annular LRNB. Waveplate creates aberration suitable for LRNB generation.

**Results and Discussions**

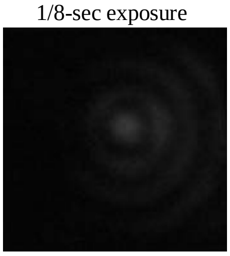
Photo luminescence images of the propagated beam on an infrared card (Newport, IRC2) are shown in Figs. 2(a), (b), (c), and (d), which provide approximate beam patterns. The images were taken for various exposures with a digital camera (Nikon, D-1) at 660 m of the distance from the transmitter.

Figs. 2(a) and (b) depict focused beam patterns with

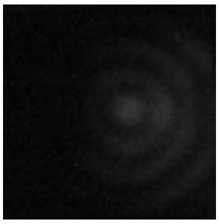
(a) Focused beam with 1/8-sec exposure



(b) Focused beam with 1-sec exposure



(c) LRNB with 1-sec exposure



(d) LRNB with 5-sec exposure

Fig. 2 Beam patterns of focused beam [(a) and (b)] and LRNB observed at 660 m away from the transmitter [(c) and (d)].

exposure times of 1/8 sec and 1 sec, respectively. Figs. 2(c) and (d) correspond to LRNB patterns with exposure times of 1 sec and 5 sec, respectively. In the case of focused beam, it spread due to turbulence even in 1-sec duration, although its spot size was close to the diffraction limit with 1/8-sec of duration. On the other hand, as for LRNB shown in Fig. 2(c) and (d), one can see clearly main lobes, even if the exposure time was lengthened to 5 seconds. As a result of this observation, we confirmed that LRNB can reduce long and short-term beam spreading.

We also measured intensity fluctuations for both the LRNB and the focused beam using an InGaAs-PIN photodiode (THORLABS, DET410) with 1 kHz of the sampling rate for 30 seconds. This photodiode collected a beam by placing a 5-cm diameter plano-convex lens with a variable aperture in front of the detector. Fig. 3

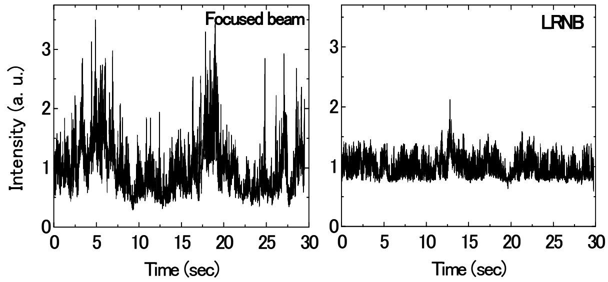



Fig. 3 Power variances of the focused beam and the LRNB caused by atmospheric turbulence.

represents a typical example of temporal power variance measured at the detector. The fluctuation of the LRNB seemed to be significantly smaller than the focused beam. Quantitatively, its standard deviations were decreased by less than half with aperture diameters of 1 cm and 5 cm as listed in Table-1.

| Aperture Diameter (cm) | σ | |
|---|---|---|
| | Focused Beam | LRNB |
| 1 | 0.60 | 0.26 |
| 5 | 0.46 | 0.18 |

Table-1 Comparison of intensity fluctuation between the focused beam and the LRNB

In conclusion, a propagation experiment of the LRNB using an annular-beam infrared laser over a distance of 660 m was performed. An appreciable reduction of turbulence-induced intensity fluctuation in the LRNB was found, and thus the experimental results strongly supported the use of LRNB for long range beam propagation in the atmosphere to effectively dwell energy on a region of interest.

**Reference**

1) T. Aruga, "Generation of long-range nondiffracting narrow light beams," Appl. Opt. **36,** 3762-3768 (1997).

2) T. Aruga et al., “Nondiffracing narrow light beam with small atmospheric turbulence-influenced propagation”, Applied Optics, vol. 38, 3152-3156(1999).

3) Y. Suzuki et al., "Generation of Long Range Non-diffracting Beam in infrared region", Proc. of 24th Japanese Laser Sensing Symposium, P-30, 141(2005)