NEWS RELEASE

NTT

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Discovery of a Novel Beam Scanning Phenomenon

- High-Speed, Compact Optical Beam Scanner is realized with KTN Crystal -

Nippon Telegraph and Telephone Corp. (NTT; Head Office: Chiyoda-ku, Tokyo; President and CEO: Norio Wada) has discovered a novel phenomenon in which optical beam is steered by simply applying an electrical signal to an electro-optic crystal[*1]) KTN ($KTa_{1-x}Nb_xO_3$, Potassium Tantalate Niobate). The new found phenomenon enabled us to realize an electro-optic (EO) beam scanner[*2]) with unprecedented performance; the scanning efficiency[*3]) of the KTN beam scanner is 80 times as high as the conventional EO beam scanner. The other features of the KTN beam scanner include wide scanning angle, high-speed response and compactness.

The KTN crystal has long been known to exhibit the highest performance among the EO crystals since 1960's. But difficulty in crystal growth prevented its use for applications until NTT Photonics Laboratories succeeded in the growth of KTN crystal with a practical size in 2003 (Fig. 1). The new beam scanning phenomenon was discovered using the KTN (Fig.2). Theoretical and experimental investigation has revealed that the beam scanning phenomenon is based on a new concept; electron injection into EO crystal (Fig. 3). The injected electrons induce gradation of refractive index[*4]) inside the crystal and the optical beam traveling through the crystal is continuously and cumulatively deflected.

EO beam scanners in general have attractive features such as high-speed response and capability of digital/analog scanning. But a drawback of the conventional EO beam scanners[*5]) is that even a small scanning angle requires a high voltage. The KTN scanner has overcome this problem and broke the record of the scanning efficiency by 80 times (Fig. 4, Fig. 5). Moreover, when the KTN scanner is compared to moving mirrors such as polygon mirrors and galvanic mirrors[*6]) which are widely used in laser printers, photocopiers and so on, the KTN scanner can improve the response time by 100 times and reduce the device volume by 1/00 while achieving a comparable scanning angle (Fig. 6).

The new found KTN scanner is expected to expand the application fields of KTN crystal not only in the optical communication but also in the printing, imaging, display, and so on with its unprecedented high performance.

Technology Highlights

1. KTN crystal (Fig. 1)

KTN crystal consists of potassium (K), tantalum (Ta), niobium (Nb), and oxygen (O). The features of KTN include a) very large dielectric constant (>10000), b) large EO effect, and c) contains no hazardous and polluting materials. The KTN crystal has long been known to exhibit the highest performance among the EO crystals since 1960's, but difficulty in crystal growth prevented its use for applications. NTT Photonics Laboratories succeeded in the growth of KTN crystal with a practical size in 2003.

2. Novel beam scanning phenomenon and its principle of operation (Fig. 2, Fig. 3)
We have discovered that the optical beam can be steered by simply applying voltage to the KTN crystal. Theoretical and experimental investigation has revealed that the beam scanning based on a brand-new concept of the electron injection into the electro-optic crystal which has been regarded as an insulating material. The phenomenon is named the space-charge-controlled EO effect. Even though the effect is applicable to any EO crystal, it manifests itself particularly in KTN crystal.

3. Unprecedented performance of the KTN beam scanner (Fig. 4, Fig. 5)
The KTN beam scanner scans the optical beam over wide angle of 12 degree. This is 80 times wider that that of the conventional prism-type EO beam scanner operating at the same condition. This high performance owes to the NTT's original technologies; the KTN crystal and the new found principle of operation.

4. Comparison with various beam scanning technologies (Fig. 6)
Optical beam scanner is the device which controls the most fundamental property of light, *direction of light*. They are widely used in various fields such as display, printing, imaging, optical storage, optical communication, and so on. The KTN beam scanner opened up the new operation regime which has never been explored by the conventional technologies.

Prospects
We will continue developing the technology for application in various fields such as communication, display, printing, and so on.

Glossary
*1 Electro-optic (EO) crystal
Electro-optic crystal changes its refractive index by applying voltage. There are two major EO effect; Pockels effect and Kerr effect. The KTN crystal possesses Kerr effect in which the refractive index is quadratically proportional to the voltage.

*2 EO beam scanner
The device which steers the light by utilizing the EO effect.

*3 Scanning efficiency
A scanning angle obtained by an EO crystal with a unit length (=1 cm) and a unit voltage (=1 kV).

*4 Gradation of refractive index
It refers to the refractive index changing gradually between the electrodes deposited on the surfaces of the KTN crystal.

*5 Conventional EO beam scanners
Conventional EO beam scanners utilize the prism-shape to refract the optical beam. The refraction angle is controlled by the EO effect but it is usually small even with an applied voltage up to 10000V. The need of high voltage prevented practical use of the conventional EO beam scanners.

*6 Polygon mirror, galvanic mirror
These are basically a moving mirror mounted on a motor shaft. They are widely used in laser printers and photocopiers. Their advantage is wide scanning angle but it is difficult to achieve high-speed response and low power consumption.

- Fig. 1 Electro-optic crystal KTN
- Fig. 2 Discovery of novel beam scanning phenomenon in KTN
- Fig. 3. Principle of operation of new found beam scanner
- Fig. 4. Comparison with conventional EO beam scanner
- Fig. 5. KTN beam scanner achieved the record-high scanning efficiency
- Fig. 6. Comparison with various beam scanning technologies

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