HCP
HC PHOTONICS CORP.

Tel: +886-3-6662123
www.hcphotonics.com
service@hcphotonics.com

GRIIRA & Laser Damage

Q: Does PPMgO: LN has gray-tracking issue?

What's GRIRA for CW SHG at 532nm?

What is the typical damage threshold for CW and pulsed applications?

A:

1. **Gray-tracking:**

   Typically MgO:cLN has neglectable gray-tracking issue.

   However, in some material such as KTP, a grey line is observed when the crystal is irradiated by visible or UV light. The induced absorption is attributed to polarons, where carriers may in that case be captured e.g. by Ti^{4+} ions or by Fe^{3+} impurities in the KTP [1]. Gray tracking is usually reversible and disappears within a few hours after irradiation. Its strength depends on the crystal quality and thus on the fabrication method, as well as some important parameters such as the pulse duration and pulse repetition rate.

2. **GRIIRA:**

   In niobates, an important difference from KTP is that the induced absorption appears to occur only for pulses with sufficiently high peak intensity. The GRIIRA (green induced infrared absorption) results from the impurity inside the material which has unbalanced ratio of Li+ and NbO3-. The induced absorption appears to be related to the formation of polarons (electrons trapped by antisite niobium ions), also called color centers, which can result e.g. from two-photon absorption.

   The effect can be greatly reduced by doping the material with magnesium oxide (MgO) and/or by using stoichiometric material, which contains fewer of the intrinsic niobium antisite defects. At the same time, both measures reduce the tendency for photorefractive beam distortions, as they increase the ionic conductivity.

   In MgO doped material, GRIIA still exists when illuminated with very strong intensity of visible/UV beam. Some research result shows that the absorption coefficient of IR wavelength will change rapidly with the visible beam on/off.

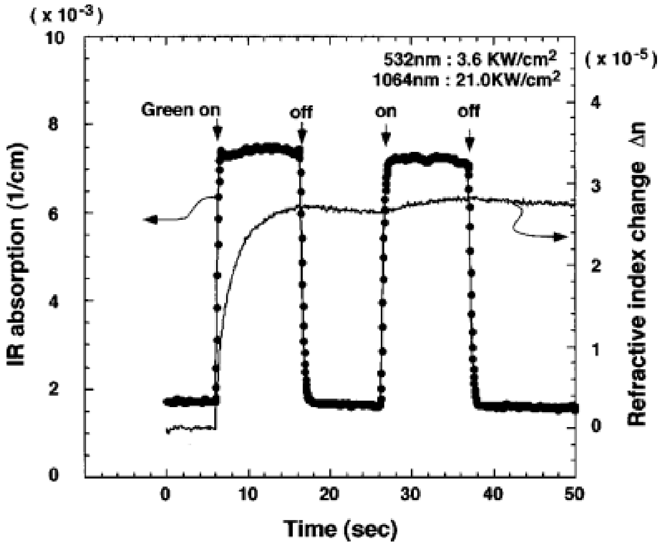

Figure 1. The change of absorption coefficient and refractive index of the IR wavelength with the presence of the visible light.

3. Damage:

The laser induced damage threshold (LIDT) is not easy to define for it is related on:

I. Spot size

II. pulse duration

III. repetition rate

IV. wavelength

V. surface quality

I. Spot size:

For same intensity/energy density, the smaller spot size will have higher LIDT, since the smaller spot size have better heat dissipation. For example, >300mW 532nm can be generated in PPLN ridge waveguide with ~6um MFD, which corresponds to >50 times of that obtained in PPLN bulk crystal.

II. Pulse duration:

The LIDT has different mechanism under the different pulse duration as shown in table below. In long pulse region, the absorption leads to increase of temperature and the crystal usually get cracked due to the non-uniform thermal distribution in the crystal. On the other hand, the short pulse can has less pulse energy and it tends to have dielectric breakdown or ionization for its strong peak intensity.

Pulse duration	<1ns	1ns-100ns	100ns-100μs	>100μs
Damage Mechanism	Ionization	Dielectric Breakdown	Dielectric Breakdown/Thermal	Thermal

Typically the ***LIDT is inverse proportional to the square root of laser pulse width***. For example, the LIDT of a 100ns pulse is 10 times lower than that of the 1ns pulse.

III. Repetition rate:

For the same intensity and same pulse duration, the lower rep. rate will give a higher LIDT since the material will have more time to dissipate the heat.

IV. Wavelength:

Typically the ***LIDT is scaled with laser wavelength*** since the photon energy is inverse proportional to wavelength. However, the visible wavelength will cause other issues such as GRIIA or PR effect in the lithium niobate, as a result the damage threshold drops quickly to short wavelength.

V. Surface quality:

The poor surface quality will lead to higher scattering and the LIDT will significantly degrade. Although all of HCP's chips are cleaned and inspected the surface quality before shipment, always clean the end-faces before using will help to avoid possible damage.

Following is a reference table that gives many test results in different pumping condition from our customer and internal experiments:

Wavelength	Laser conditions/Operation	Focusing parameter	Intensity	Damaged?
1064nm	CW, 12W, SHG	120	0.1MW/cm^2	N
1064nm	CW, 10W, SHG	80	0.2MW/cm^2	Y
1064nm	Pulsed, 7ns, 4.2kHz, 1W, OPG	200	110MW/cm^2	N
1064nm	Pulsed, 7ns, 4.2kHz, 1W, OPG	50	440MW/cm^2	Y
1550nm	CW, 30W, SHG	80	0.6MW/cm^2	N
1560nm	Pulsed, 100fs, 80MHz, 2W, SHG	50	25.5GW/cm^2	N
1030nm	Pulsed, 130ps, 1kHz, 3.5W, OPCPA	500	6.7GW/cm^2	N
1560nm	CW, 60W, SHG	73	1.4MW/cm^2	N

Reference:

[1] B. Boulanger *et al.*, "Study of $KTiOPO_4$ gray-tracking at 1064, 532, and 355 nm", Appl. Phys. Lett. 65, 2401 (1994)

[2] H. Mabuchi *et al.*, "Blue-light-induced infrared absorption in $KNbO_3$", J. Opt. Soc. Am. B 11, 2023 (1994)

[3] Y. Furukawa *et al.*, "Green-induced infrared absorption in MgO doped $LiNbO_3$", Appl. Phys. Lett. 78, 1970 (2001)

[4] J. Hirohashi *et al.,* "Characterization of GRIIRA properties in LiNbO3 and LiTaO3 with different compositions and doping", Proc. of SPIE 6875 687516-1 (2008).

[5] Y. Furukawa *et al.,* "Optical d a m a g e resistance and crystal quality of LiNbOs single crystals with various [Li]/[Nb] ratios", J. Appl. Phys. 72 (1992).