Inradoptics

Zinc Germanium Phosphide (ZGP)

Zinc Germanium Phosphide (ZGP) is one of those few reliable, efficient, high quality non-linear crystals that is beginning to dominate applications in a particular spectral region due to the unique properties of the material. A high non-linear coefficient (75 pm/V), good thermal conductivity (35 W/mK), relatively high Laser Damage Threshold (2-5 J/cm^2 typically), and transparency with phase-matchability over the 2 µm – 8 µm range (and beyond) highlight the desirable properties of the material.

Inrad Optics has been a recognized leader in producing the highest quality ZGP crystals for quite some time, and, recently, has increased production output. Key factors for successful production of this unique crystal include synthesis of the raw starting charge from the chemical elements, precise control of growth conditions with several post-growth processing steps for improved quality, and accurate fabrication that includes orientation, cutting, and grinding. High-quality polishing minimizes sub-surface damage to realize the innate performance from the crystal, and thin-film coating enables optimization in demanding applications. An inventory of material allows us to respond promptly to requests for prototype crystals.

APPLICATIONS

ZGP is a key component of the laser source used in infrared countermeasure (IRCM) systems to protect aircraft from heat-seeking missiles. This critical application requires a mid-IR source with high power and tunable operation through the 3-5 micron atmospheric window. Since availability of laser sources in the mid-IR is limited, nonlinear frequency conversion of mature 2 micron sources with ZGP provides a well-proven approach for reaching mid-IR wavelengths. ZGP has the highest thermal conductivity and nonlinear coefficient of commercially-available materials. ZGP optical parametric oscillators (OPOs) have demonstrated tunable operation throughout this range with up to 27 Watts of power. Recent advances in 2 micron fiber laser technology have increased the potential of ZGP for use in ruggedized, compact optical setups. Pumping ZGP with a fiber laser instead of a solid-state source could substantially reduce the footprint of the entire system.

ZGP also has been used to generate terahertz (THz) wavelengths. The THz absorption in ZGP is lower than almost all other nonlinear materials, facilitating tunable conversion of 2 micron sources into THz by difference frequency generation. Producing optical sources in the THz portion of the electromagnetic spectrum (between the far-IR and microwave regions) historically has been elusive. However, it remains intriguing due to the wide variety of potential applications. Many organic compounds and explosives have their strongest signatures in the THz region, spurring the need for reliable sources. Since many optically opaque materials (including fabrics, paper, and cardboard) are transparent to THz radiation, concealed weapons can be detected with a non-ionizing THz source, which obviates safety concerns, for example, that are present when using alternate X-ray methods. Other demonstrated uses for THz imaging include detection of flaws in aircraft, screening for cancer, and identification of dental issues. There also is potential for THz imaging in military brown-out conditions encountered during helicopter landings or in desert convoys.

Additional applications, of course, are possible. Once a crystalline material reaches a certain level of perfection, it becomes a tool for realizing new applications.

Examples of crystalline ingots of ZGP along with oriented OPO blanks.

CRYSTAL GROWTH & PRODUCTION

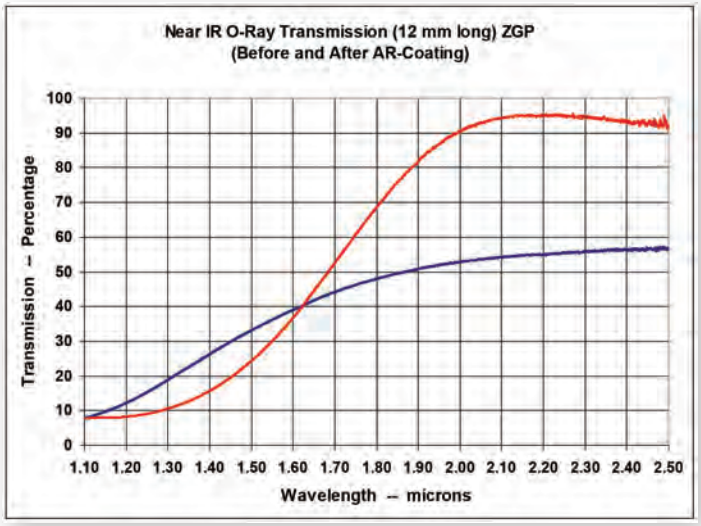
Crystal growth of ZGP is a multi-step process, developed and refined at Inrad Optics over the past 20 years. Government support through small business innovation research (SBIR) funds during the 1990s, and additional funding from NASA, NSF, and the Navy, enabled us to bring high-quality ZGP to commercial production.

Crystals are grown at high temperature by a horizontal gradient freeze technique. Examples of single-crystal ingots and fabricated OPO blanks are shown above.

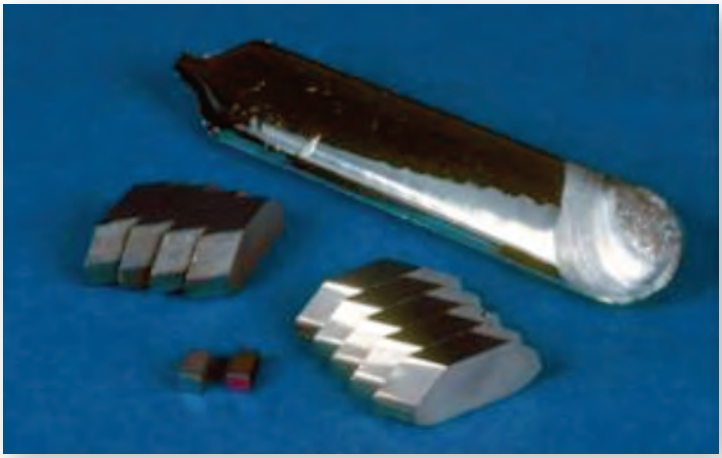
Crystal fabrication, polishing, and testing of ZGP is performed at our Northvale, NJ facility. All ingots undergo post-growth treatment to improve optical transmission and homogeneity, and are characterized by x-ray diffraction and optical methods to ensure that the material meets our exacting specifications.

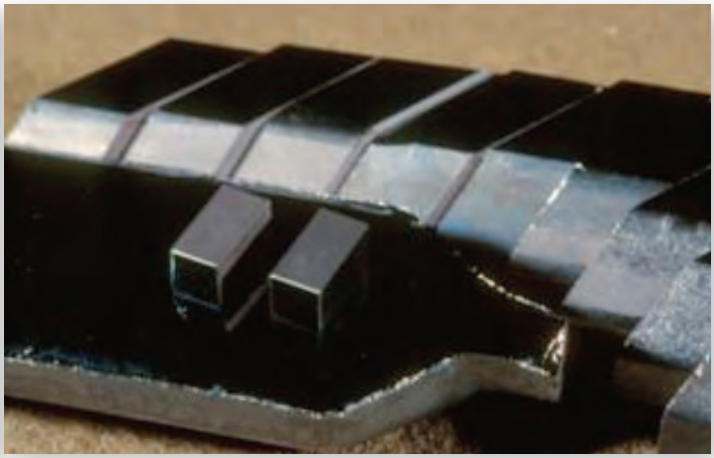
Examples of crystalline ingots of ZGP, oriented slices, and finished OPO crystals.

Anti-reflection (AR) coatings are applied by our in-house coating facility. The high refractive index of ZGP often requires application of anti-reflection (AR) coatings on polished surfaces for increased transmission efficiency. An example of transmission improvement in the near-IR is shown in the plot below. The low transmission of the uncoated 12 mm long crystal is due to the high Fresnel losses of polished surfaces, originating from the high refractive index of the material, as well as, inherent absorption. Refractive indexes of ZGP at 2.1 µm are 3.15 for the o-ray and 3.18 for the e-ray. Application of an AR coating to both polished faces dramatically increases transmission in the areas where the coating is optimized. For OPO applications, in which the pump wavelength is near two microns, the polarization direction of the pumping wavelength coincides with the o-ray direction in the crystal.



Near-IR ordinary-ray transmission of ZGP crystal before and after AR-coating. Note the pump polarization direction coincides with the o-ray for an OPO pumped near two microns.





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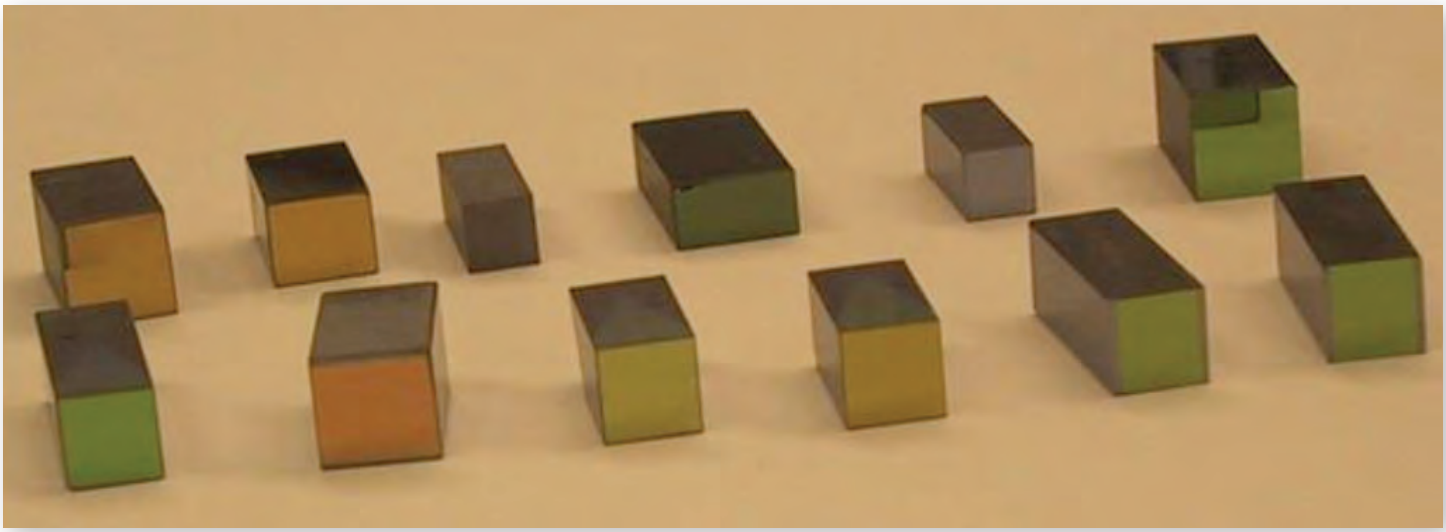

Sampling of ZGP crystals with various outlines and optical coatings.

ZGP crystals for mid-IR generation have been sold by Inrad Optics since 2000 and we recently have tripled our production capacity to improve material availability. Starting in July 2013, we are pleased to announce availability of standard, off-the-shelf ZGP crystals, available for prompt delivery. Standard dimensions are 6 mm x 8 mm x 15 mm, oriented with θ=54° for Type I OPO operation with a 2.09 micron pump.

In addition, we routinely produce ZGP optics to customer specifications, and we welcome custom inquiries.