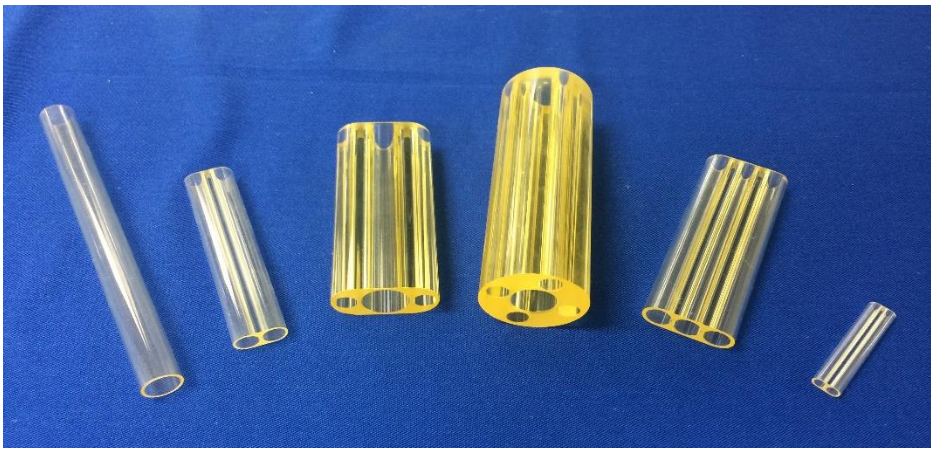
Cavity Filters

Kigre, Inc.'s expertise in laser glass technology has led the way in the company's development of a wide range of cavity filter glass for solid-state lasers. Filters are used inside the laser cavity to enhance beam amplification by matching the frequency of the wavelengths corresponding to the appropriate pump bands. They also absorb unwanted UV and IR radiation.

Kigre's filters are strengthened after fabrication using proprietary method which tempers the filter with approximately five times the strength of normal glass. This added strength extends the operational life and makes the glass harder.

Kigre manufactures filters in a wide variety of sizes and configurations, ranging from simple flow tubes and slides to complete cavity custom filters for a wide range of applications.



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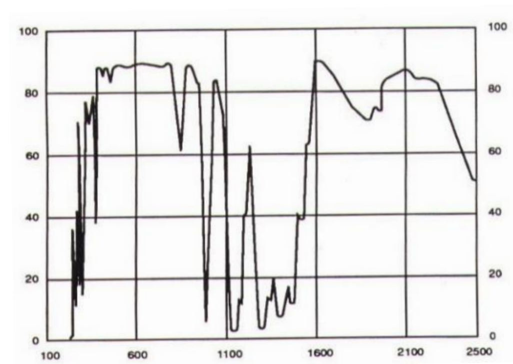
Filters for improved laser efficiency

KSF-5/KSF-10 Samarium Filters

Kigre's Samarium filters are made from KSF filter material. Developed by Kigre, his material is a high transmission, high strength, glass doped with samarium and sensitizer ions. KSF-5 has 5% samarium doping; KSF-10 has 10% samarium doping. KSF absorbs one micron and unwanted UV and IR radiation while transmitting and reinforcing at wavelength corresponding to the Neodymium pump bands.

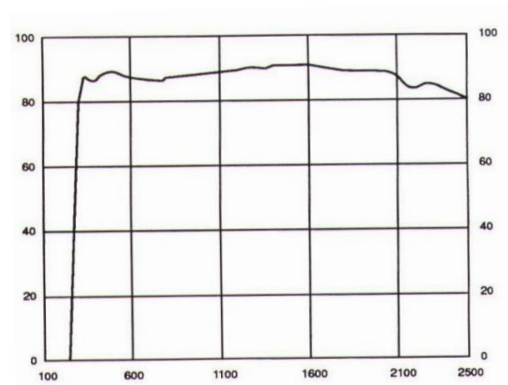
Kigre's KSF filters are manufactured in a variety of sizes and configurations. These configurations range from simple flow tubes and slides to complete cavity assemblies with barium sulfate over coating. An added benefit – KSF filters are strengthened after fabrication using proprietary method with tempers the filter with approximately five times the strength of normal glass.



KF-2

KF-2 filter material is ideal for improving the efficiency of glass laser systems. KF-2 is available in a number of sizes and configurations.

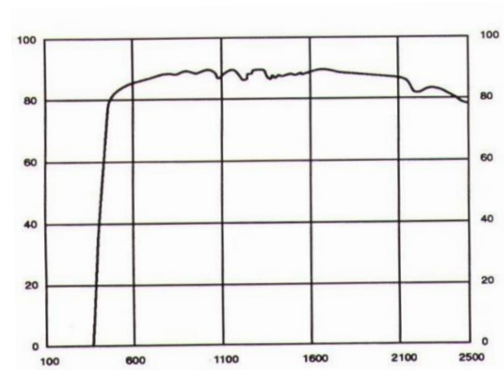
CUT-OFF POINT (2% Transmission 2mm sample) …300nm



KC-331

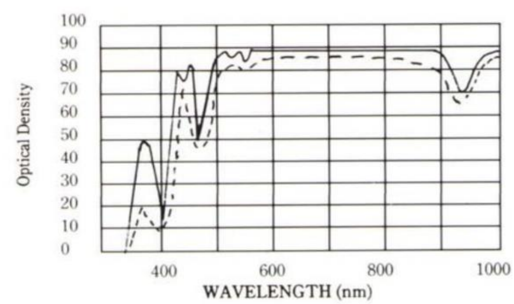
KC-331 was developed especially for use with easily solarized UV-sensitive materials such as Alexandrite. As an added feature, KC-331 contains properties which make it radiation resistant.

CUT-OFF POINT (2% Transmission 2mm sample) …347nm



KK-1

Kigre manufactures another proprietary Samarium doped radiation hardened filter material designated KK-1. The adjacent transmission curves demonstrate KK-1's radiation resistance. These curves were generated from a KK-1 sample, exposed to 46,070 rads/minute of Co-60 gamma radiation for 22 minutes. The total dose rate was 1 mega rad Si. Courtesy Sandia National Laboratories.



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Filters for improved laser efficiency

Filter Glass properties	KSF-10	KSF-5	KF-2	KC-331
UV Cutoff (2mm) (2%transmission)	375 nm	325 nm	300 nm	347 nm
IR Cutoff	2500 nm	2500 nm	2500 nm	2500 nm
Optical Density (at 1.06 microns)	1.0/cm	0.5/cm	NA	NA
Index of Refraction (D line of Sodium)	1.575	1.563	1.554	1.553
Thermal expansion (x10 exp(-7/deg. C) 25-300 deg. C	113	118	114	110
Thermal expansion (x10 exp(-7/deg. C); 0-100 deg. C	99	79	85	84
Softening Temperature in deg. C	501	487	488	502
Density (g/cc)	2.66	2.56	2.55	2.56
Modulus of Rupture, psi (after strengthening)	50K	50K	50K	50K
Fluorescence output color (visible)	Orange	Pink	NA	Blue
Acid resistivity (HNOe o.5M) Class Fl	Pass	Pass	Pass	Pass
Thermal conductivity (W/mK)	1.3	1.3	1.3	1.3
Knoop Hardness kg/sq.mm (Hk for 100g load)	600	600	600	600
Poisson's ratio	0.24	0.24	0.24	0.24

Customized glasses are also available though Kigre's "Specialty Glass Group". Fore more information ask your Kigre Sales Representative about Kigre's "Special" Melts.

Solid-state laser pump cavity reflector

During the 1970's and 1980's Kigre developed a series of intra-cavity filters and solid state, diffuse reflectors based upon very unique high performance designs. Numerous manufactures have employed Kigre cavity reflectors and filter flow tubes into their standard line of commercial and OEM laser products. Competitive attempts to match Kigre's cavity reflector performance have consistently fallen short of the mark. "other" design only have been able to emulate to a limited degree the wide operational envelope, unlimited lifetime, and overall performance of the real thing. Kigre's close-coupled intra-cavity reflector assemblies exhibit spectral management properties that are unsurpassed in performance by any other cavity.

Comparison of reflective materials (%R):

Wavelength (nm)	Gold	BaSO4	Silver	Aluminum
300	0.35	0.95	0.10	0.95
400	0.33	0.99	0.99	0.93
500	0.40	0.99	0.98	0.92
600	0.76	0.99	0.98	0.91
700	0.92	0.99	0.99	0.90
800	0.94	0.99	0.99	0.90
900	0.94	0.99	0.99	0.90
1000	0.95	0.99	0.99	0.90

Diffuse Reflector Pumping Cavity Attributes

1. Multi-pass Absorption

A diffuse pump cavity reflector assembly in many ways similar to an integrating sphere. The flash lamp or arc lamp energy is diffusely reflected many times before being absorbed in the active gain media.

Specular reflectors are designed to focus emitted light from the flash lamp into the active gain media. Little if any consideration is given to light that may have passed through the gain media due to weak absorption or Fresnel reflection. This energy is absorbed in either the pump chamber reflector or reabsorbed in the flash lamp media.

In a diffuse reflector pump cavity, light that has passed through the active gain media has a good probability of passing through the media gain, allowing for further absorption of some of the weakly absorbed flash lamp spectra. Depending upon reflector, rod and flash lamp geometry, the flash lamp energy may pass through the active gain media up to two times more in a diffuse reflector pump cavity chamber than in a specular reflector pump cavity. In practice, this allows the laser engineer the ability to reduce the dopant concentration or the diameter of the active gain media without sacrificing efficiency. This can be advantageous when pumping a highly absorbent gain media at high average power.

2. Resistance to Degradation

Most medium or high power lasers that utilize specular pump cavity reflector require active cooling of the reflector. The two most commonly used methods include direct coolant contact with the reflection or conduction though the reflector into a heat sink. In either case the lift of the reflector is limited because of impurities in the coolant or differences in thermal expansion or quite simply corrosion.

Kigre's series of diffuse reflector pump cavity assemblies utilize a reflector that is in the form of a high-density powder separated from the coolant by a glass flow tube. The powder (Barium Sulfate BaSo4), is an extremely inert compound guaranteeing long life. In order to ensure long lift and high performance Kigre utilizes a proprietary powder purification and densification process.

Because of the reflector and the protection of the filter/flow tube, the lift of the Kigre pump cavity reflector assembly is indefinite if the coolant used is rather pure (usually ~1MOHM/cm H2O). Many Kigre pump cavity reflector assemblies have been providing decades of service without maintenance.

3. Parasitic Oscillation Suppression

In high gain laser media, parasitic oscillations may limit the maximum stored energy and thus maximum gain. This is particularly true for materials like Nd:YAG when used as q-switched oscillators or amplifiers. It is possible in pumping chambers utilizing specular reflectors, that parasitic oscillation path may reflect off the specular reflector itself limiting or "clamping" the stored energy.

Unlike a specular reflector, a diffuse reflector provides a near Lambertiam distribution, reducing the possibility of parasitic oscillations reflection off the pump chambers reflector, Kigre pump cavity reflector assemblies provide further parasitic suppression through the use of a doped flow tube or "filter tube". Kigre manufactures filter tubes doped with various dopants for nearly all solid state laser materials.

4. Pumping Uniformity

Specular reflector cavity reflectors are often engineers to provide as uniform pumping as possible, often at the expense of efficiency. When specular reflector pumping chambers are designed for maximum efficiency the pimping uniformity is usually quite poor leading to “hot” spots in the laser output beam and uncorrectable thermal lensing in the laser rod.
The near Lambertian distributions of diffuse reflections provide the diffuse reflector pumping chamber with significantly improved pumping uniformity over that of specular reflector pump chamber designs. Because of the rod is illuminated more symmetrically, it is easier to compensate for thermal induced lensing and birefringence.

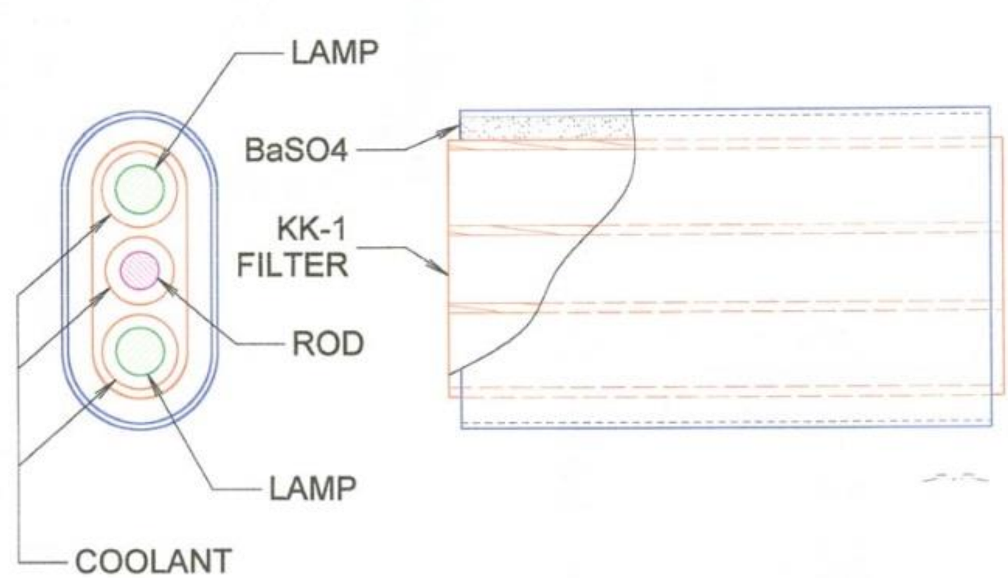
5. Higher reflectivity than Gold, Ceramic, or Silver reflectors

In addition to the inertness of the diffuse reflector, BASO4 has higher reflectivity (better than 98% from 375nm to 1.3 microns) than gold, ceramic, or silver coatings. The high reflectivity coupled with the inertness provides superior performance over specular reflectors.

6. Higher Efficiency

More of the flash lamp or arc lamp energy is coupled into the active gain media with a diffuse reflector than with a specular reflector. Under equal pumping conditions, the diffuse pump cavity offers reduces threshold, increased slope efficiency, overall efficiency, more stored energy, and higher gain.

PUMP CHAMBER DIFFUSE REFLECTOR



7. Unique advantages of Kigre Diffuse Reflector Pump Cavity Reflector Assemblies

Kigre pump cavity reflector assemblies are constructed with the diffuse reflector placed on the outside of the glass filter tube. The filter tube is usually placed on the outside of the glass filter tube. The filter tube is usually in the shape of a double or triple barrel shotgun with a web of glass separating the active gain media bore from the flash lamp or arc lamp bore. Since the index of refraction of the glass between the rod and the lamp is higher than water or air, the active gain media is optically 'moved' closer to the flash lamp or arc lamp providing even closer coupling for higher efficiency.

Through doping the filter tube, portions of the flash lamps spectrum that are unwanted may be filtered from reaching the gain media. The solid state gain materials that are somewhat sensitive to UV solerization maybe protected by such a filter tube. Depending upon the nature of the gain media, Kigre utilizes Cerium and Samarium and other dopants to absorb ultraviolet (UV) and portions of the visible spectrum. Some of this absorbed energy is emitted through fluorescence in a spectral region that is absorbed by the gain media. By absorbing the non-useful portions of the lamp's spectrum, the temperature of the gain media can be lowered, reducing thermal effects such as lensing and birefringence.

Kigre's diffuse reflector pump cavity reflector assemblies utilize a "close coupling" design for maximum efficiency. In addition to the increased efficiency, the diffuse reflector pump cavity is usually smaller in size and mass than comparable specular pump cavities.

Useful optical pumping of solid state laser material usually is in the region of 400 – 1300 nm. Kigre has designed its diffuse reflector pump cavity assemblies to transmit flash lamp or arc lamp light that is no longer than 1.5 microns and less than 3 microns through the diffuse reflector, reducing absorbed heat in the gain media and thus reducing lensing and birefringence.

Kigre has manufactured several thousand diffuse reflector pump cavity reflector assemblies during the last 3 decades that accommodate solid state laser rods ranging from 3mm Ø x 30mm to 25 mm Ø x 600 mm. In most situations a pump cavity reflector assembly has been already designed for a customer's specific needs; However, many custom filter/flow tubes and reflector assemblies are fabricated each year.