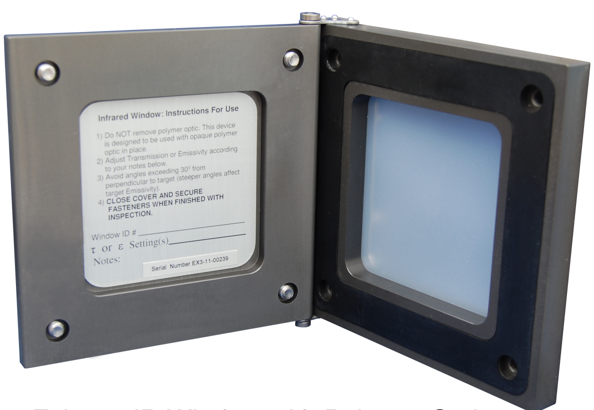
EXISCAN™
Closed-Panel Inspection Windows

Comparison:
Exiscan™ IR Windows v/ Crystal Windows

> *"How many times do I have to tell ya' lad? 'The right tool for the job!'"*
>
> *Mr. Scott*
> *(Star Trek V)*



Exiscan IR Window with Polymer Optic

Typical CaF_2 Crystal Optics

Of the available options in the infrared (IR) window market, the choices generally fall into two categories: polymer or crystal optics. Neither is a *universally* superior or inferior solution -- instead the suitability of one window technology over another is dependent upon the application and environment in which the window will be used.

Exiscan is focused predominantly on industrial applications. As such, this overview will focus on the differences between IR window solutions and their technologies, as they relate to the inspection of industrial power distribution equipment (switchgear, transformers, MCCs, termination boxes, etc).

CalciumFluoride Crystals

The most common IR window crystal used in electrical thermography is CalciumFluoride (CaF_2), however some manufacturers may be referred to trademarked names. It's popularity over other crystals is based primarily on its *comparatively* low cost. IR crystals such as Barium Fluoride (BaF_2), Germanium (Ge), Zinc Selenide (ZnSe) all have superior transmission characteristics, but all are more expensive when compared to CalciumFluoride.

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Technology Maturation

Predictive Maintenance technologies have traditionally begun their lives as proven laboratory measurement technologies: expensive and fragile, but effective. In the early days of vibration analysis, engineers wheeled expensive and fragile HP analyzers, onto the paper mill floor to monitor rollers. Using $2,000 accelerometers connected by delicate, impossibly thin wires, they proved that one could identify and fix imbalance and a host of other mechanical faults. Similarly, the original infrared imagers were wheeled around on carts, cooled by compressed gas and cost more than the average house. They too proved effective. Recognizing the value that these technologies could bring to the market, but also recognizing the inherent environmental incompatibilities of the laboratory versions, innovative instrumentation manufacturers ruggedized their equipment to withstand the unique demands of the industrial environment.

Today, these technologies can be dropped on concrete floors. They are able to withstand wet and harsh environments. Sensors now cost under $100 and IR cameras have broken through the $1,000 threshold. These technologies have made a full transition from expensive and fragile laboratory instruments to rugged and cost effective industrial tools.

The same process is happening with infrared windows. Infrared windows have been used in laboratory settings since the beginning of thermography. The laboratory crystals have now been proven effective in helping to safely identify electrical faults, but their durability and cost have prevented them from being broadly accepted in the market. Exiscan™ has now produced a line of industrial grade IR windows -- ruggedized and suitable for use outside the controlled environment of the laboratory, and affordably priced for broad implementation.

Why are crystal optics round?

Recall that the crystal optic originated in the laboratory. In laboratory applications, a round optic was sufficient and more cost effective than its square counterpart:

(1) A four-inch diameter round crystal uses significantly less material and production time than a four-inch square crystal, and therefor costs less.

(2) Because laboratory work is performed shooting straight ahead (as opposed to shooting at angles like we do in the field), the optic shape can match the shape of the imager lens without the interfering with the image. Since the corners of a square optic are only used when shooting at angles, the additional material would be an unnecessary expense in a laboratory application. (Why would a laboratory only shoot straight-ahead? Because shooting at various angles through a thick crystal affects the relative thickness of the crystal depending on the angle of incidence. The steeper the angle, the more crystal must be penetrated, consequently, the lower the transmission rate. The resulting temperature inaccuracies would not be acceptable in a laboratory application, therefore data is taken straight ahead.)

(3) Square crystals are more fragile than round, making them more expensive to manufacture, transport and use.

(4) Because of the reasons detailed above, round crystal are the predominant shape purchased, and therefore manufactured. Therefore, economies of scale make them even more economical compared to square crystals.

Viewing Area

With a unique, square aperture, Exiscan™ has increased the optic viewing area by more than *two-thirds* compared to traditional round crystal optics.

Comparison of "Four Inch" IR Windows

	Aperture Dimension	Aperture Viewing Area	Size Advantage
Exiscan™	4" x 4"	16.00"	**+66.3%**
CaF_2 Windows	3.5" diam	9.62"	

Comparison of "Three Inch" IR Windows

	Aperture Dimension	Aperture Viewing Area	Size Advantage
Exiscan™	3" x 3"	9.00"	**+186.6%**
CaF_2 Windows	2.7" diam	3.14"	

Whereas crystals are measured edge to edge without regard to the amount of area that the housing eclipses, Exiscan™ measures its optic across the actual viewing aperture. For example: Exiscan's aperture is four-inches by four-inches square. The leading "four-inch" crystal window is just 3.5 inches in diameter.

The square optic further adds additional viewing area over a round aperture. While the leading "four-inch" round window yields 9.62 sq. inches of viewing aperture. The four-inch square aperture measures a full 16 sq. inches of viewing aperture. More than a 66% advantage in viewing aperture area. When comparing "three-inch" IR windows, Exiscan™ has close to three times the viewing area of similar sized crystal windows.

The unique square design also gives the user an additional viewing area advantage: the corners are squared, like the imager display. This allows a thermographer to use the full width and height of the window aperture without clipping the edges of the image (a round window will crop the image when shooting at angles). The result is additional viewing area that goes beyond the calculations.

Exiscan's™ polymer optic will not react to industrial environments, and therefore does not need special coatings. Just like a car requires paint to prevent the steel from rusting, crystals require delicate coatings that protect them from environmental factors that cause them to lose their ability to transmit infrared radiation. Because these coating are delicate, the manufacturers recommend that thermographers maintain a safe two-inch distance between their camera lens and the crystal optic. What effect does this added distance have on field of view? Imagine looking at a construction site or a baseball game through a knothole in a fence -- you can see a great deal through that small hole. Now imagine pulling back two-inches -- what effect would that have on how much you could see?

Exiscan's™ unique, square polymer optic provides the best field of view of any similar-sized, IR window on the market.

Impact Resistance

There is a reason that your mother did not let you use her "good crystal" when you were younger: it was fragile. And there is a good reason that the ANSI/IEEE C37.20.2 standard for switchgear, clearly prescribes impact resistance requirements (section A.3.6) for "a transparent material covering an observation opening and forming a part of the enclosure…" Due to the inherent fragility of crystals at the thickness used for infrared windows, it is not possible for these optics to pass the ANSI/IEEE standard that clearly applies to them. It is this standard, that caused the industry-wide shift from glass inspection-windows to the Lexan™ windows used today. (Unfortunately, Lexan™ does not transmit IR radiation, otherwise it would be the perfect IR window material.)

Conversely, Exiscan's™ patented optic made of a formed polymer, easily passes and exceeds this standard. Similarly, it passes UL standards for impact resistance (UL 746C), which CaF_2 windows are again unable to pass.

Transmission Rate

The IR cameras used for infrared inspections today are tuned to the 8 to 14 micron (8µm to 14µm) range -- usually referred to as "long wave infrared" or LWIR. Polymer offers superior LWIR transmission characteristics. Exiscan's™ XIR polymer optic has an effective transmission rate of roughly 68% in this critical range for industrial predictive maintenance imagers.

CaF_2 crystal optics have an effective transmission of roughly 50% due to the variability of the transmission at various wave lengths from 7µm (where it's transmission is over 90%) to 10µm and beyond, where it's transmission is close to zero. The variability of transmission across this waveband (referred to as "spectral transmission") actually causes the crystal to yield different transmission rates depending on the temperature of the target object, thereby making proper calibration for temperature accuracy all but impossible with a CaF_2 optic.

To put it simply, the transmission rate of the crystal for a 105° fuse is different than it is for the 120° fuse next to it. Without a consistent and known transmission rate, it is impossible to accurately calibrate one's imager.

This transmission variability based on target temperature would not be a significant drawback in the laboratory, where mid-wave infrared (MWIR) imagers are commonly used. In the MWIR spectrum (3µm to 8 µm range), CaF_2 transmits beautifully at over 90%, making it a great choice for laboratory work, but clearly not the material of choice for anyone seeking temperature accuracy in electrical thermography. But Exiscan's™ polymer optic is well suited to task for this niche application.

In fact two of the three manufacturers of CaF_2 infrared windows readily admit the limitations of the technology when used with todays LWIR cameras. For more information on this topic, see:

- Madding; *IR Window Transmittance Temperature Dependance*; Inframation, 2004
- Holliday; *Understanding Infrared Windows and their Effects on IR Readings*; UpTime Magazine; Oct/Nov 2012; p22-26

Transmission Stability

Exiscan's™ polymer optic was specifically selected because of its ability to maintain mechanical integrity and transmission rate when exposed to environmental factors such as moisture, humidity, vibration, harmonics and a broad spectrum of acids and alkalis. Such environmental factors are not an issue in a controlled laboratory setting, however, they are in many industrial and facilities maintenance applications.

Where Exiscan's™ polymer optic is inherently resistant to those environmental factors, crystals are not. Therefore, it is standard practice to coat CalciumFluoride and other crystals to protect them from the effects of moisture humidity and chemicals. This coating is microscopically thin to avoid serious transmission effects. (Any time the imager is shooting through additional material, there must be a corresponding transmission degradation based on the transmission characteristic of that material.) Due to the thin application of the coating, it is not uncommon for such sealants to be incomplete (especially on the cut edges of the crystal), or damaged during use. That is why the transmission rate of some crystals demonstrate a degradation in transmission rate over time, while others from the same batch may retain a 50% transmission rate after years of use. It is worth noting that no coating can reduce the effects of vibration or mechanical shock on crystal.

For more information on this topic, see:

- DeMonte, Is *What You See, What You Get?;* UpTime Magazine, Apr 2009; pg 24
- Doherty, Newberry & Shewe; *Opening the Windows*; UpTime Magazine, Nov 2007; pg 22.)

These environmental factors are not an issue in a laboratory because the environment is controlled. In a laboratory setting, it is also common practice to periodically calibrate critical instrumentation to make sure that measurements are accurate. An easy process in most laboratory applications. However, field-calibrating a window installed in electrical equipment would involved opening the equipment -- not a practical solution for industrial use, since the reason for installing the IR window is to eliminate the need for opening the equipment.

Structural Integrity

Exiscan™ designed its IR windows for maximum structural integrity. The window is bolted through the enclosure, and through a stainless steel support plate (positioned inside the enclosure). The multiple bolted positions ensure even and complete load distribution in the event of a blast in the enclosure. The 16 gauge stainless steel support plate is over-sized, to help keep any enclosure distortion outside the edges of the IR window, thereby maintaining a flush mount so that heated gases do not escape the edges of the window mount. Exiscan windows have also passed arc resistance testing on switchgear, per the ANSI/IEEE C37.20.7 standard.

The entire body is machined out of half-inch bar stock aluminum or stainless steel, with a 0.4-inch thick cover that is secured in multiple positions with ¼-20 stainless steel screws. The goal was to build a window that would be stronger than the enclosure it was installed on, so that our clients would never have to question what effect the window would have on the structural integrity of their enclosure.

For corrosion resistance, Exiscan™ only uses aluminum and stainless steel hardware and body components. Aluminum windows are first anodized, and then powder coated, for maximum protection in harsh environments. Units made entirely of stainless steel are also available.

Summary

Crystals and polymers both have their place in the world of infrared windows. Crystal windows are best suited to laboratory applications in controlled environments. CalciumFluoride specifically, is best suited to laboratory applications using short wave/ mid-wave IR imagers, or in applications of intense heat (such as furnaces). Exiscan's™ polymer optic was engineered and is best suited to industrial and facilities maintenance applications, such as electrical inspections. The polymer has superior and stable transmission characteristics, it is impact resistant per ANSI/IEEE and UL standards. It offers significant size advantage which affords thermographers greater field of view. Exiscan™ has engineered it's housing, cover and mounting design for superior structural integrity, in keeping with and surpassing electrical enclosure standards. Finally, Exiscan delivers its solution at a significant savings when compared to the crystal alternatives on the market.

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For more information on this and related topics, visit: www.Exiscan.com

Comparison of Exiscan XIR Series and Competitors' Crystal Windows

	Exiscan	CaF_2 (1)	CaF_2 (2)
UL 50V Recognized	Yes	Yes	Yes
Impact Resistant Optic	Yes	No	No
Aperture Viewing Area: 4 inch IR Window	16.00"	9.64"	9.79"
Aperture Viewing Area: 3 inch IR Window	9.00"	5.79"	5.63"
Effective Transmission Rate	~68%	~50%	~50%
Transmission Rate 10µm and higher	~68%	<10%	<10%
Transmission/Temperature Accuracy	Yes	No	No
Inherently Stable in Industrial Environment	Yes	No	No
Through-Bolted in Multiple Positions with Stainless Steel Backer-Plate	Yes	No	No
Available in Stainless Steel	Yes	No	No
NEMA 4 or 4X	Yes	4 Only	No
Arc Flash Tested (KEMA)	Yes	Yes	Yes
Suitable for Low, Medium & High Voltage	Yes	Yes	Yes
Retail Price: 4 inch	$365	$599	$650
Retail Price: 3 inch	$325	$379	$399

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