Window Substrate Guide

Applicable Products	Window Substrate Kits		
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Purpose

This guide is intended to present the standard available optical window substrates for a Montana Instruments cryostat, the use cases of each substrate type, and the advantages and disadvantages of each. Montana Instruments can support different window materials in a cryostat system. Contact our sales team to discuss your specific application requirements.

Background

There are a variety of optical window options available for use within an optical cryostat. Properties, performance, and cost can vary greatly depending on the window material. The main performance characteristics of an optical window for use in a cryostat system are determined by transmission and thermal properties. Transmission is the window's ability to allow a specified wavelength to pass through it. Certain windows are designed to be used in the visible light spectrum, while others are designed to be used in the ultraviolet to the far infrared range. Windows in a cryostat have two placements – on the vacuum housing and the radiation shield. The purpose of having two windows in the cryostat is not just for transmittance and optical access. The vacuum housing window needs to seal the sample chamber off from atmospheric conditions, and therefore must be able to withstand the atmospheric pressures forced upon it. The radiation shield window needs to mitigate the radiative heat load entering the sample chamber, which helps to achieve lower sample temperatures. While the outside of the vacuum housing is generally at room temperature, the radiation shield inside the housing reaches sub-30K temperatures. The platform inside the radiation shield is at or below 4K (depending on other connected components and wiring, this temperature may be higher). Certain windows cannot be used at such low temperatures, making the temperature of the operating environment another critical consideration when selecting optical windows for use in a cryostat system. Figure 1 demonstrates the difference in temperatures between the radiation shield and the sample chamber platform.

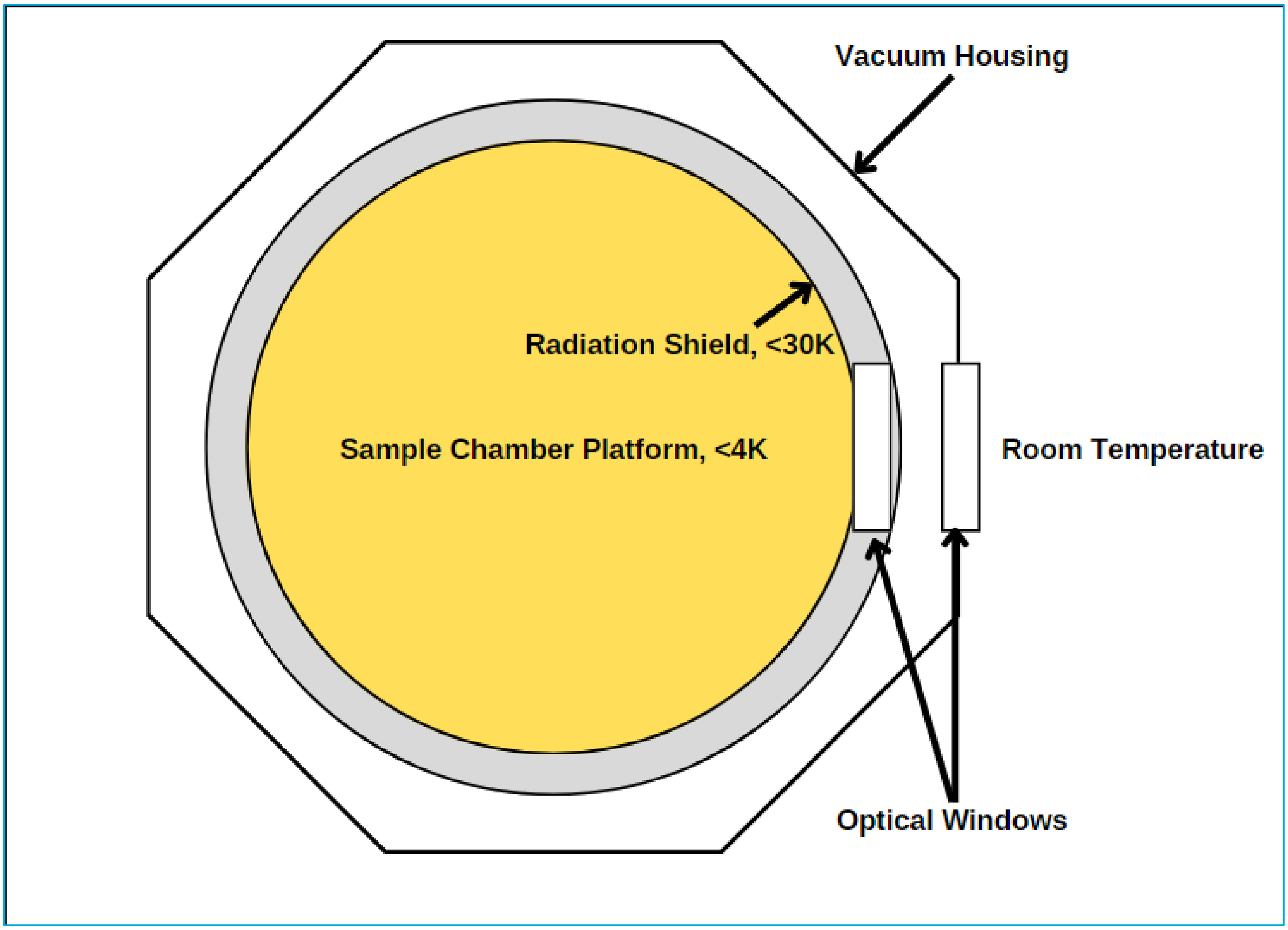
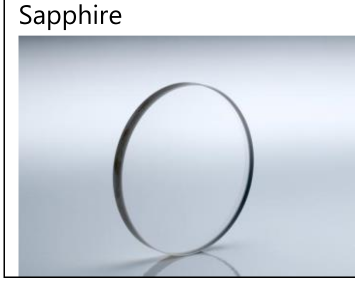


Figure 1: Difference in temperature between cryostat stages with an example of installed optical windows on a 50mm platform.

Optical window selection must also include consideration for other disadvantages that come with certain windows, such as poor scratch resistance or birefringence (also called double refraction, it is an optical property of a material to split plane-polarized light into two rays as it passes through the material). For example, experiments with high-power lasers require specific window substrates that have a high damage threshold (a point past which a window is damaged due to laser output) to survive extended use as well as adequate wavelength transmission for optimal performance and successful completion of the experiment. Selected windows can be further tailored to specific experimental applications by applying coatings. Anti-reflective and specific wavelength range coatings are common types of coatings that can be applied to most windows. Wavelength range coatings improve transmission in a specific range. Note that coatings affect other performance aspects of optical windows. For example, a trade-off of an anti-reflective coating is that it reduces the optimal wavelength range of the window on which it is applied to. For further detail, refer to Figure 4.

Applicable Theory

Optical window selection for use in a cryostat is dependent upon three main factors: wavelength range, the intensity of the electromagnetic radiation experienced during the experiment, and the temperature of the environment in which the windows will be present. The selected window must be able to filter out undesired waves while also allowing the specific waves of interest to pass through, throughout the temperature range of the system. Table 1 lists a selection of commonly used window substrates and the range of wavelengths they can be used in, their specific use cases, and the advantages and disadvantages of each available substrate type.

Substrate	**Optimal Performance Wavelength Range**	**Use Cases**	**Advantages**	**Disadvantages**
BK7 	300nm-2µm, ultraviolet, visible, near IR	Low-power laser systems	Low distortion and dispersion	Limited wavelength range
Fused Silica- VIS-NIR Coating 	400nm-1µm, visible, near IR	Laser experiments, emitter/detector protection devices, specific near IR applications	Standard option; coating reduces surface losses within wavelength range, can be used inside and outside the cryostat sample chamber, low thermal expansion, higher transmission in range	More limited wavelength range, greater potential for impurities, coating can be damaged with improper use and storage
Fused Silica 	200nm-2µm, ultraviolet, visible, near IR	Laser experiments, emitter/detector protection devices, ultraviolet imaging systems	Can be used inside and outside the cryostat sample chamber, can be coated (anti-reflective, etc.), low thermal expansion	Limited wavelength range, greater potential for impurities, potential for heat generation and damage at some shorter UV wavelengths
Sapphire 	300nm-5µm, ultraviolet, visible, mid-IR (extreme IR below 80K)	High-temperature environments (up to 500K), IR applications	Extreme surface hardness can be made thinner than other widows, scratch-resistant	Birefringent

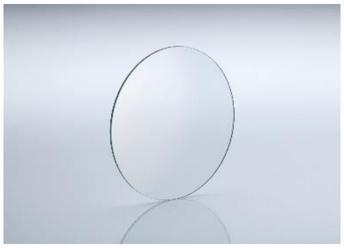
Calcium Fluoride 	200nm-8μm, ultraviolet, visible, mid/far IR	Spectroscopic windows, excimer laser optics	High transmission in wavelength range, low absorption, high damage threshold, low index of refraction	
TPX	80-2000μm, extreme IR, THz 400nm-1μm, UV, visible, near IR	THz transparency	Transparent in UV, visible, and THz ranges, can be used as cold windows	Porous to helium gas (causes increase in system temperature by ~1K, potential for vacuum leaks if helium gas contact with window is not limited)
Zinc Selenide 	700nm-17μm, visible to mid/far IR (often has 3-12μm coating for IR)	Infrared applications-Thermal imaging, FLIR	Low absorption, high shock resistance	Scratches easily, toxic to bare skin and eyes, and if ingested; handle with care (also reacts with acids to produce toxic hydrogen selenide gas)

Table 1: Summary of different window substrates, their wavelength ranges, use cases, and advantages/disadvantages. Ordered from least to most expensive.

Images from Knight Optical.

Figures 2 and 3 provide the transmission percentages for each window substrate in their wavelength range.

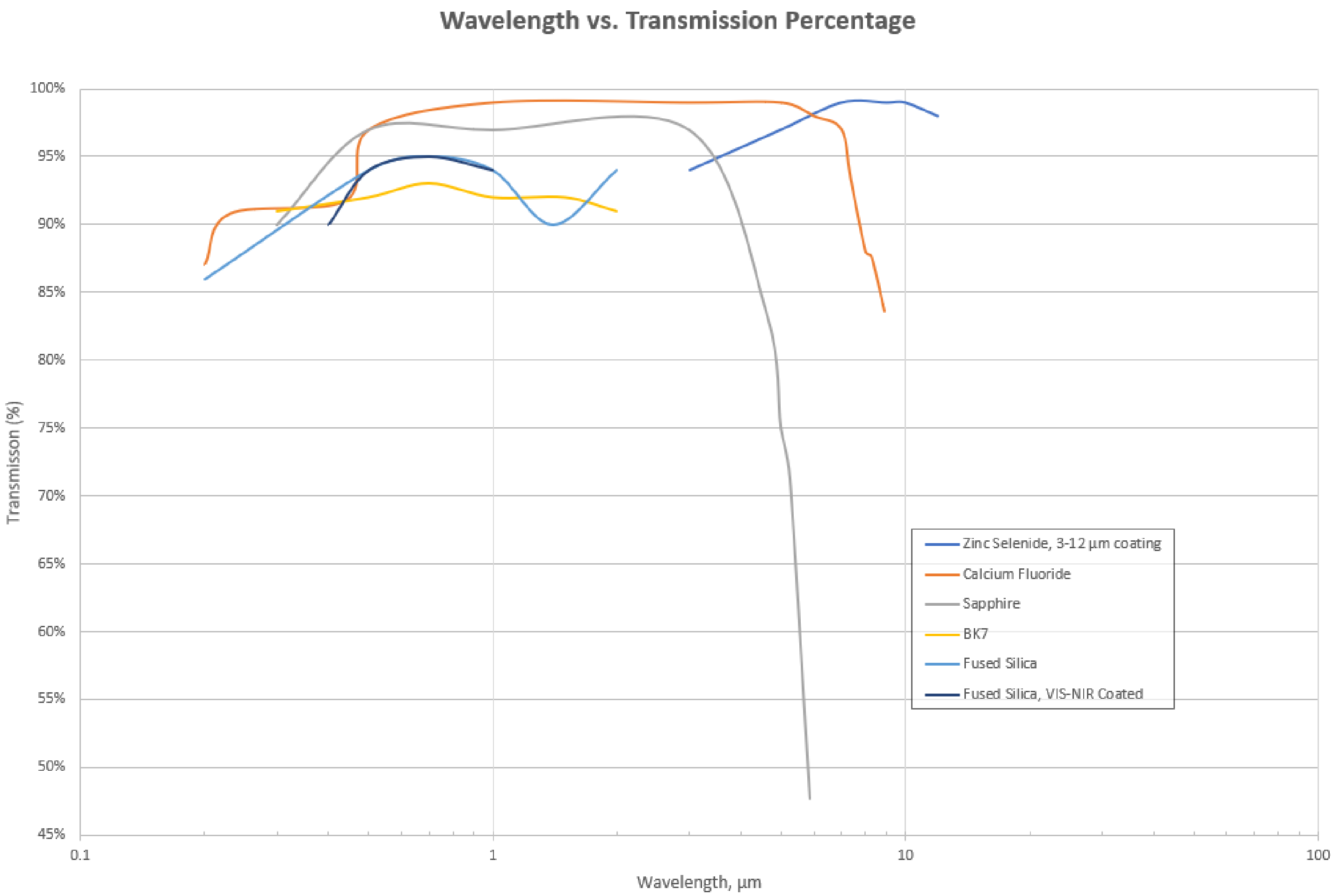


Figure 2: Wavelength vs. transmission percentage for a selection of optical window substrates.

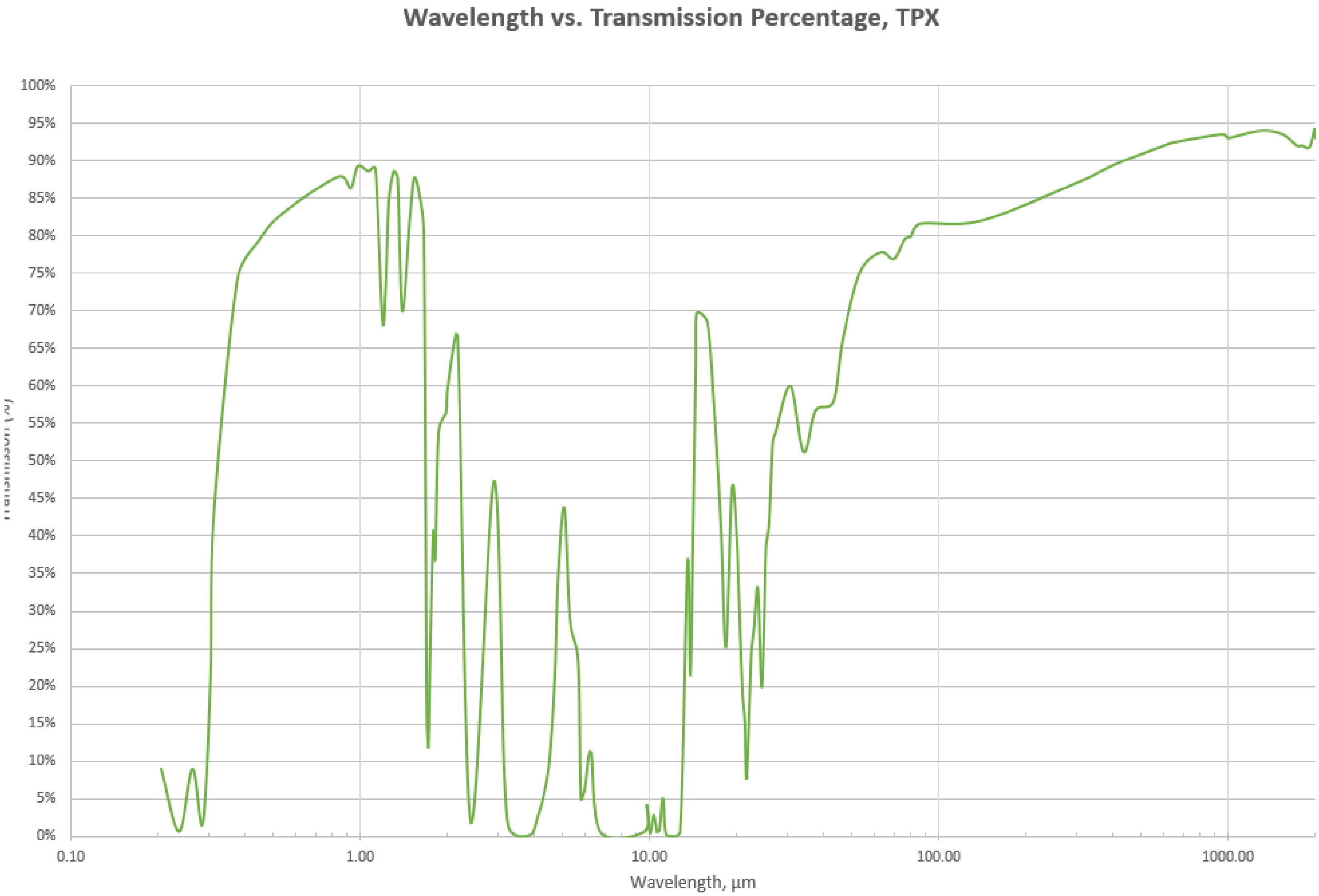


Figure 3: Wavelength vs. transmission percentage for a TPX optical window.

Figure 4 displays where a selection of window transmission ranges fall within the electromagnetic spectrum.

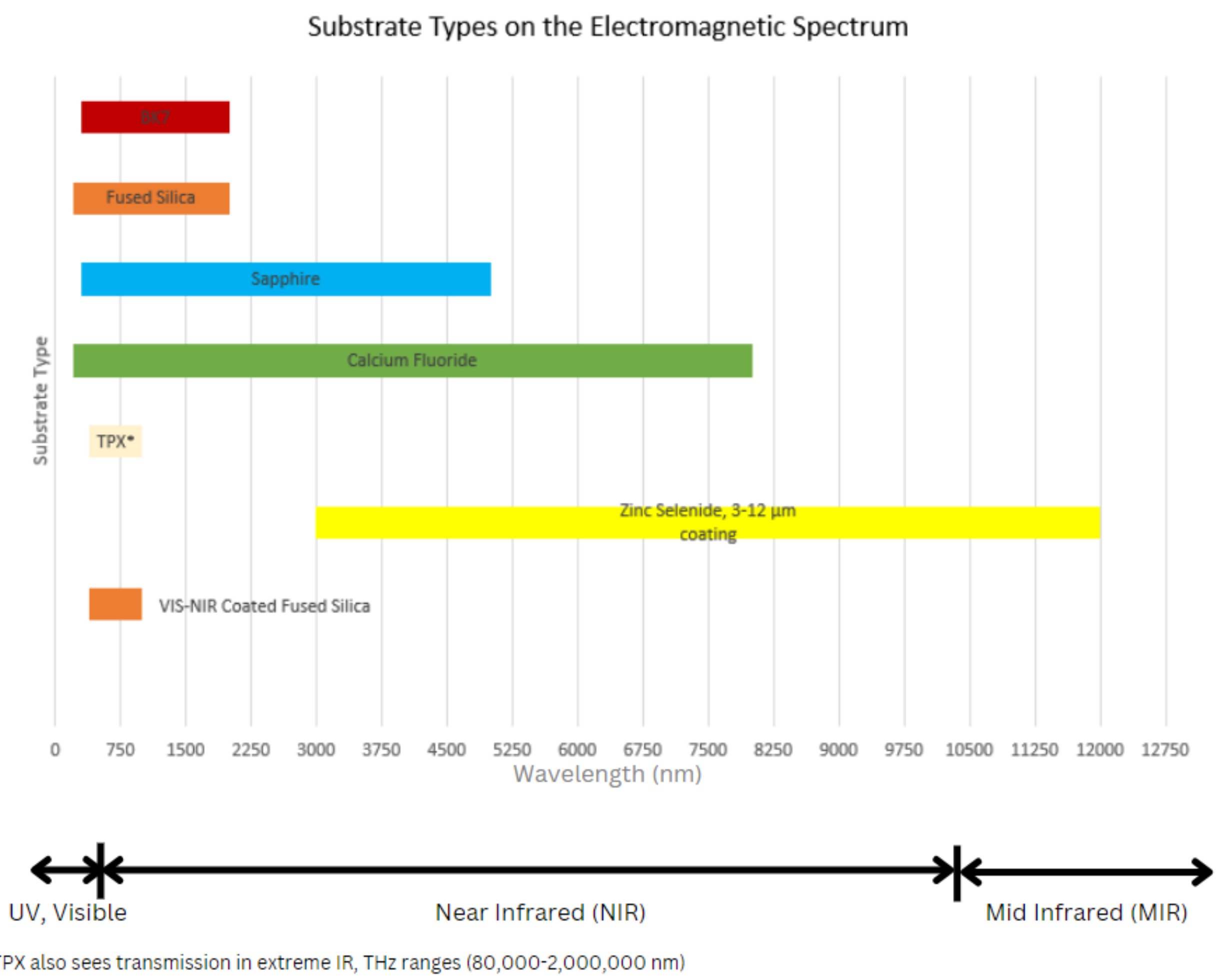


Figure 4: Selection of window substrates and where their transmission ranges fall within the electromagnetic spectrum.

Summary

Cryogenic experiments involving sources of electromagnetic radiation often require specialized optical windows. Window types can vary greatly depending on material properties, performance, and cost. Montana Instruments offers a wide selection of window substrates to fit a variety of customer use cases.

References

[1] https://www.montanainstruments.com/products/w01

[2] https://www.knightoptical.com/stock/default/windows-and-diffusers.html

[3] https://www.rp-photonics.com/optical_windows.html

[4] https://www.edmundoptics.com/knowledge-center/application-notes/optics/understanding-optical-windows/