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Technology Offer

Optical Fiber Feedthrough for a Vacuum Chamber

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Abstract

This invention relates to an optical fiber vacuum feedthrough designed to transmit optical signals between the inside and outside of the vacuum chamber. Traditional methods often require frequent replacement of flanges or optical fibers due to leakage over time, and the high pressure applied to the optical fibers led to transmission losses. In order to address these issues, the presented optical fiber feedthrough comprises a compression device which compresses sealing elements axially along the passage openings in order to exert a radially inwardly directed compressive force on the respective optical fibers. This design reduces vacuum chamber leakage, minimizes operational costs, and supports the transmission of high-quality optical signals.

Background

In a vacuum chamber, a flange is used to feed an optical fiber through while maintaining the chamber's vacuum, enabling optical signal transmission between its interior and exterior. One approach is to position fiber optic cables in through holes of a vacuum flange and securing them with epoxy resin adhesives. However, these rigid connections are prone to leaks over time or as a result of bake-out processes, necessitating frequent replacements of both flange and the fiber optical cable. Another approach is a flange with a radially compressed elastomer gasket through which an optical fiber is passed. However, this has drawbacks, such as the limited sealing effectiveness of radially compressed gaskets and the risk of transmission loss due to the radial pressure applied to the optical fiber. Therefore, an improved feedthrough is needed ensuring that the airtightness of the vacuum chamber reduces the need for part replacements, and minimizes transmission loss.

Technology

An optical fiber feedthrough for transmitting multiple optical fibers between the interior and exterior of a vacuum chamber includes a compression device, such as a clamping mechanism, which compresses sealing elements arranged within the passage openings to create a pressure-tight seal around each fiber (Figure 1 provides a schematic of the optical fiber feedthrough). The sealing element, which is axially compressed between the compression device and a flange sealing receptacle, expands in the radial direction of the optical fiber, securing it in place. For example, the compression device may comprise a metal compression plate and an interposed sleeve arranged between the compression plate and the sealing element (as shown in Figure 2). The compression plate provides an axial force along the passage openings, which is transmitted to the sealing elements via the interposed sleeves, exerting an radial inward compression around each optical fiber. In this way, this invention enables a vacuum-tight feedthrough of multiple optical fibers with low transmission loss.

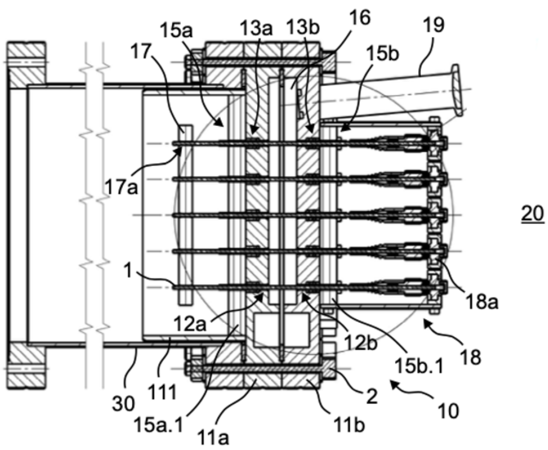

Figure 1: Optical fiber feedthrough 10 for transmitting multiple optical fibers 1 inside a vacuum chamber 30. Flanges (11a, 11b) have passage openings (12a, 12b) through which one optical fiber 1 passes, and are attached to the vacuum chamber 30 using fastening elements 2, for example, threaded bolts. Each of the passage openings 12 has a sealing receptacle (13a, 13b) and a sealing element (14a, 14b), and a compression device (15a, 15b) is attached to the flange 11 to axially compress the sealing element 14 along the passage opening 12. A support device 17 is provided for supporting and mounting the optical fibers 1, and multiple optical fibers 1 are used with a coupling device 18 to form an optical fiber assembly 20.

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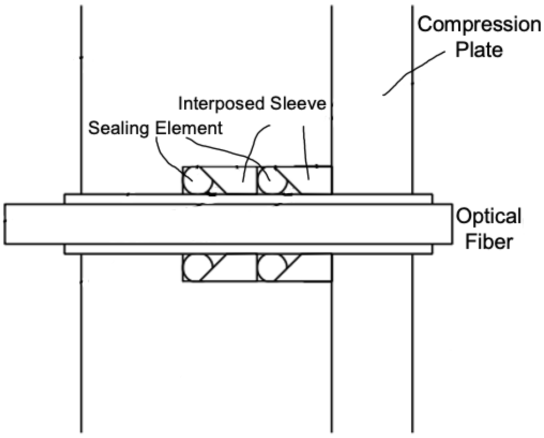

Figure 2: Example of a passage opening 12 for one embodiment. The compression device has a metal compression plate and an interposed sleeve. The interposed sleeve is placed in the sealing receptacle of the passage opening and transmits the compressive force to the sealing element. The sealing element expands radially due to the transmitted axial compressive force and exerts a compressive force radially inward on the optical fiber. As shown in the figure, multiple sealing elements may be provided for a single opening to further enhance tightness.

Advantages

- **High airtightness:** Ensures secure sealing for sustained vacuum, reducing leakage risk.
- **Reduced maintenance:** Minimizes the need for flange and cable replacements, lowering operational costs.
- **Multiple-fiber feedthrough:** Supports the secure passage of multiple optical fibers simultaneously, enhancing efficiency and versatility.
- **Reduced transmission loss:** Precise, controlled compression minimizes pressure on the optical fibers, maintaining high signal quality and reducing transmission loss.

Potential applications

- **Spectroscopy and analysis:** Enables precise optical signal transfer for spectroscopic analysis of materials within a vacuum environment, such as in mass spectrometry and X-ray spectrometry.
- **Imaging and Real-Time Monitoring**: Supports optical imaging and monitoring in vacuum conditions, crucial for plasma research, particle accelerators, and other advanced physics applications.
- **Laser processing and material modification**: Facilitates laser delivery in vacuum-based material processing systems, used for creating microstructures and altering material properties.

Patent Information

DE application (DE10 2023 121 227.3), pending in EP and US
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