CEN/CENELEC Workshop Agreement

CWA XXXXX

Draft Version 2.2 – 2021-10-26

Lens-based adaptor system for coupling fibre optic to mid-infrared (MIR) and other types of semiconductor lasers

Foreword

This is a draft for public commenting. Foreword text will be finished in the final draft version, upon the following structure:

This CEN/CENELEC Workshop Agreement (CWA XXXXX:202X) has been developed in accordance with CEN/CENELEC Guide 29 "CEN/CENELEC Workshop Agreements – A rapid way to standardization" and with the relevant provisions of CEN/CENELEC Internal Regulations – Part 2. It was approved by a Workshop of representatives of interested parties on XXXX-XX-XX, the constitution of which was supported by CEN and CENELEC following the public call for participation made on 2021-08-03. However, this CEN Workshop Agreement does not necessarily include all relevant stakeholders.

The final text of this CEN/CENELEC Workshop Agreement was provided to CEN and CENELEC for publication on XXXX-XX-XX.

Results incorporated in this CWA received funding from the European Union's Horizon 2020 research and innovation framework programme under grant agreement No 856533 (MIRACLE).

The following organizations and individuals developed and approved this CEN/CENELEC Workshop Agreement:

-
-

Attention is drawn to the possibility that some elements of this document may be subject to patent rights. CEN and CENELEC policy on patent rights is described in CEN/CENELEC Guide 8 "Guidelines for Implementation of the Common IPR Policy on Patent". CEN or CENELEC shall not be held responsible for identifying any or all such patent rights.

Although the Workshop parties have made every effort to ensure the reliability and accuracy of technical and non-technical descriptions, the Workshop is not able to guarantee, explicitly or implicitly, the correctness of this document. Anyone who applies this CEN/CENELEC Workshop Agreement shall be aware that neither the Workshop, nor CEN or CENELEC, can be held liable for damages or losses of any kind whatsoever. The use of this CEN/CENELEC Workshop Agreement does not relieve users of their responsibility for their own actions, and they apply this document at their own risk. The CEN/CENELEC Workshop Agreement should not be construed as legal advice authoritatively endorsed by CEN and CENELEC.

Introduction

The common solution for coupling a mid-infrared (MIR) laser to an optical fibre is using parabolic mirrors. This solution provides a very low optical loss because of coupling. However, using a parabolic mirror comes with a few disadvantages.

For example, such a coupling is bulky so it makes the laser-based devices bigger and difficult to assemble, which renders the final product less affordable. Additionally, if the device contains a parabolic mirror, moving it around might change the performance of the device due to mechanical vibration and might need service. Another drawback is that if a laser or fibre must be replaced, a very highly trained technician is needed to perform the replacement and coupling with the parabolic mirror. This leads to an undesirably long repair time.

Therefore, using the parabolic mirror as the fibre coupling method has three disadvantages: the bulky nature of the mirrors, being susceptible to mechanical vibration, and difficulty to service. These problems advised to look for a user-friendly and stable alternative coupling system, which will be highly beneficial for final applications of the devices. This adaptor-based coupling system makes the coupling just a plug-in process which can be done with a short training. Furthermore, using this adaptor makes the system very stable and less sensitive to mechanical vibration and shocks.

The adaptor is a lens-based coupling system, which is attached to the laser. For most MIR wavelengths, such lenses are commercially available. The lens adaptor-based coupling technique is a well-established technique for diode laser so implementation of this technique for MIR and other types of semiconductor lasers will be a smooth transition from the mirror-based coupling technique. Thus, it could be very easy for the industry to accept it as a standard method. In addition to all the technical benefits of a lens-based adaptor, the overall cost of the devices will be cheaper in comparison to the mirror-based coupling system.

The device covered by this document was firstly developed as a side result of the European, public funded research and innovation project MIRACLE ‘Mid-infrared arthroscopy innovative imaging system for real-time clinical in-depth examination and diagnosis of degenerative joint diseases’. The project uses a quantum cascade laser system to create a mid-infrared attenuated total reflection (MIR-ATR) instrument for arthroscopic use. When testing the first prototypes, different performance and design problems were found related to the coupling of the laser units to the fibres, so a new solution was developed. This same solution can be useful in quite different applications in several fields for which MIR lasers are increasingly used, such as infrared spectroscopy for different applications (pharma, biotech, environment…), medical equipment, non-metal laser processing, microscopy, laboratory tools for scientific applications, and many more.

1 Scope

This document defines design and performance requirements and guidelines for a lens-based coupling adaptor system for fibre optic, intended for coupling fibres to mid-infrared and other types of semiconductor laser sources.

Safety requirements are not covered by this document.

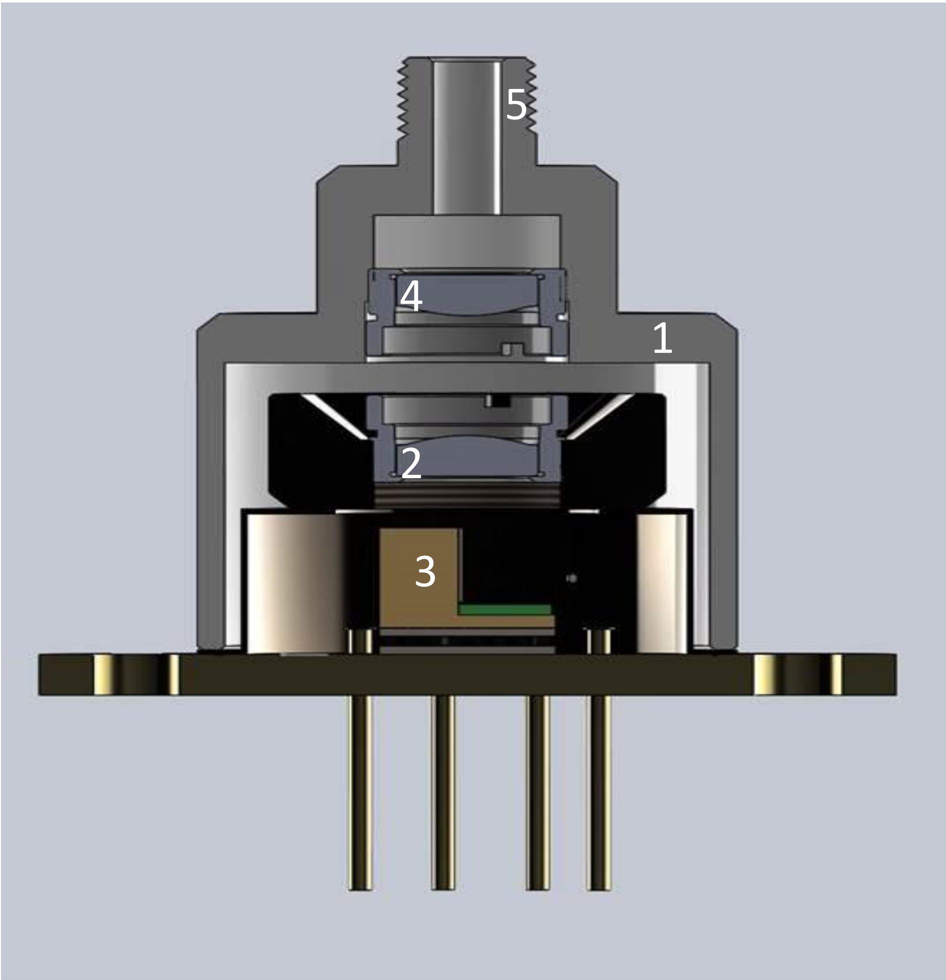
2 Description of the adaptor and coupling method

The adaptor is a single-piece machined element (cap) that fits the laser housing and is mechanically attached to it. Internally, it incorporates a glued lens that focuses the laser light into the fibre end facet.

The adaptor can be coupled to the laser by a trained person using a microstage device with three-axis of freedom.

After coupling, the adaptor is fixed to the laser with an adhesive. This assures minimal displacement of the adaptor for reaching the highest possible coupling efficiency.

Figure 1 shows the cross section of the adaptor coupled to a laser.



1- Adaptor cap
2- Collimation lens
3- Laser
4- Focusing lens
5- Thread to fix the fibre

Figure 1 - Cross-section of the laser and adaptor

3 Performance guidelines

Adaptors can be designed for single mode (SM) fibres or multi-mode (MM) fibres. The main difference is the focal spot size on the facet of the attached fibre, which depends on the optical properties of the laser beam and the focusing lens. A general rule for the spot size cannot be given because of the large variety of possible laser and lens combinations. Normally it is possible to perfectly adapt the system to a selected fibre type and diameter.

The adaptor is not limited to the MIR lasers and can be used for other types of semiconductor lasers.

The power loss of the MIR laser after coupling using the adaptor is around 50%, due to reflection and transmission losses of the additional lens. This can be minimized by the use of a properly selected lens material in combination with a dedicated anti-reflection coating on its surface.

This loss is higher in comparison with the coupling through parabolic mirror, but in turn, the assembly is much more robust against mechanical vibrations and much easier to handle. Depending on the wavelength of the laser, a suitable fibre material should be used to get the lowest possible power loss. Furthermore, the laser power should be calculated high enough to compensate for the total loss.

4 Design requirements and guidelines

4.1 Cap

The cap can be manufactured on different materials. In general, a non-reactive material that is stable for the application environment is recommended.

The dimensions of the cap depend on the application, the laser package and the final device.

Tolerances:

- The general fabrication tolerance should be ISO 2768-m according to EN 22768-1 (ISO 2768-1).
- The rules for the edges should be according to EN ISO 13715.

The cap should also be completely sealed because any external gas or dust could potentially change the lens surface, which could decrease the performance and the lifetime of the device.

Optical grade adhesive should be used to fix the adaptor after coupling with the laser.

4.2 Lens

The lens in the adaptor shall be identical to the collimating lens of the laser. For semiconductor lasers, an aspheric lens shall be used.

The lens should be coated with an anti-reflection layer. The layer reduces power loss as well as interference.

An adhesive with low shrinkage after curing is recommended. The shrinkage of the adhesive could lead to a lower coupling efficiency.

Annex A (Informative)

Example of use: the MIRACLE Arthroscopy device

The MIRACLE project designed the first mid-infrared attenuated total reflection (MIR-ATR) arthroscopy system prototype. It enables quantitative evaluation of articular cartilage composition providing a quantitative diagnosis of cartilage injuries and degenerative joint diseases such as osteoarthritis. The principle is based on the molecular vibration of the molecules which constitute the cartilage tissue (for example, amides and proteoglycan). MIRACLE team identified which wavelengths were clinically relevant to distinguish healthy from damaged cartilage.

The device is composed by seven quantum cascade lasers (QCL) providing the required wavelengths for biodiagnostics, an integrated beam guide and combiner for efficient radiation coupling without the need for any dielectric mirrors or refractive gratings, and a handheld, miniaturised MIR-ATR probe with an innovative hook-like design for cartilage assessment. The internal components are assembled into a main unit.

To illustrate the lens-based adaptor system for coupling a mid-infrared laser beam into a fibre, the following figure shows the setup of a single laser mounted on a driver unit and connected to an output fibre.

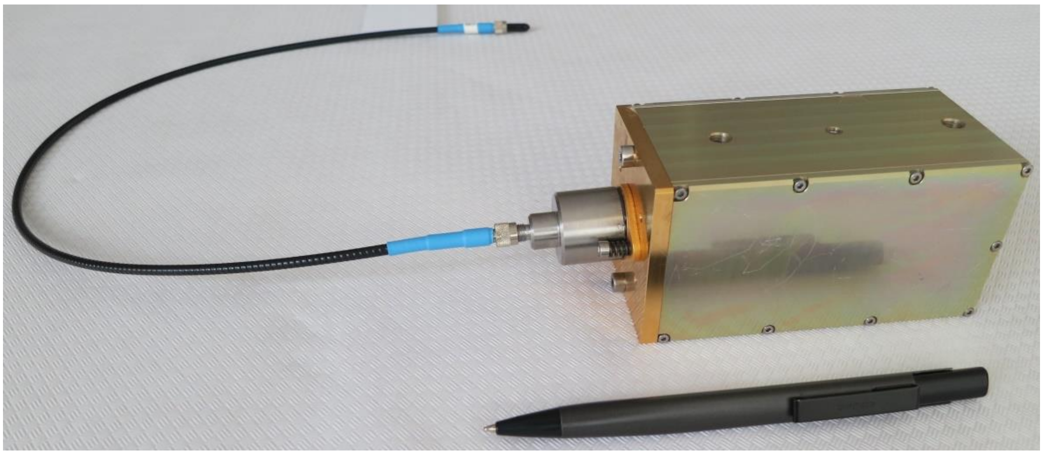


Figure 2: Setup of a single laser mounted on a driver unit and connected to an output fibre

Figure 3: MIRACLE 19" unit containing 7 lasers as depicted in figure 2 and one detector

Further specifications of the device are:

Modular and flexible multi-laser infrared light source and sensing unit for high quality (spectroscopic) measurements in the infrared region, comprising:

- Up to 7 lasers (Interband-Cascade Lasers and/or Quantum-Cascade-Lasers) in TO-3 or TO-66 housings.
- The spectral coverage depends on the laser selection/specifications (typically in the range of 3-12 microns).
- The optical output power and the spectral features depend on the selected lasers.

All 7 internal laser drivers are individually software-configurable:

- The lasers can be driven in CW or pulsed mode.
- With pulse currents from 10 mA to 4.5 A.
- Pulse repetition rates between 10 kHz and 8 MHz.
- Pulse lengths between 10 ns and 255 ns.
- Temperature stabilized (accuracy better 3 mK), with operation temperatures between -10 °C and 40 °C.
- The free space beam of each laser is internally fibre-coupled and available on the front panel of the main unit through corresponding F-SMA output connectors, or alternatively incorporating an internal coupling of all lasers and only one output.
- Suggested core diameter of the fibres is 240 microns (tests were performed with fibre core diameters up to 900 microns).

The implemented radiation detection module:

- Allows the simultaneous detection of all 7 lasers (operated in pulsed mode); one measurement every 25 ms containing a set of 7 values (one for each laser).
- Highly sensitive and low noise radiation detection using a peltier-cooled MCT detector (typical SNR > 2000) / other detector elements upon request.
- The input beam is delivered through a fibre with a F-SMA connector.

The lens-based adaptor was specifically designed to save space, facilitate the coupling process and maintenance, and avoid misalignments and interferences due to probe movement.

The coupling was tested in practice within the MIRACLE project. It shown in comparison to the mirror-based coupling a suitable performance and a much higher reliability in terms of insensitivity against mechanical shocks and vibrations. e.g., after a movement of the device to another location (lab) there was no need of realignment of the laser beam anymore. Furthermore, the saving of space was a great advantage, which allowed a much more compact design of the device.

Bibliography

EN 22768-1:1993, General tolerances - Part 1: Tolerances for lineal and angular dimensions without individual tolerance indications (ISO 2768-1:1989).

EN ISO 13715:2019, Technical product documentation - Edges of undefined shape - Indication and dimensioning (ISO 13715:2017).

MIRACLE project: www.miracleproject.eu