LUMENTUM – Response Report to PFAS Restriction Proposal

Date of submission: September 23rd, 2023

Sectors and (sub-)uses

Sector:	Electronics and semiconductor
Sub-Use:	Electronics
Use Category:	Electronic components
Sub-use:	Optical fibers for lasers (PFAS polymer coated optical fiber)
Area of use/application(s):	Low Refractive Index coating (RI<1.38)
PFAS name:	Fluoropolymer

Summary

- LUMENTUM is **requesting full exemption** of Fluoropolymers from the proposed PFAS restriction, for their **use in low refractive index coatings, in laser fibers.**
- Fluoropolymer coatings are used in and are essential to laser fibers technology.
- Fluoropolymers used in primary coatings allow for a refractive index (RI) below 1.38.
- Alternative polymer materials cannot achieve an RI<1.38 and are not available on the market.
- Without fluoropolymers, LUMENTUM would have to cease production of laser fibers in EU and without the laser fibers, the entire Kilowatt Fiber Lasers and some Ultrafast Lasers could not be manufactured.
- The impacts of banning fluoropolymers in laser fibers would be significantly negative for our company's revenue, our employees, our customers, and the entire industry that uses Kilowatt Fiber Lasers and Ultrafast Lasers in the manufacturing processes.
- Fluoropolymers are low risk materials to human health and the environment.
- Impact of banning fluoropolymers would be disproportionate compared to the potential benefits.

Response to Question 8: Other identified uses – Analysis of alternatives and socio-economic analysis.

Use of low refractive index fluoropolymers in LUMENTUM's laser products

Industrial lasers

LUMENTUM produces high-performance industrial lasers, including Kilowatt-class Fiber Lasers and Ultrafast Solid-state Lasers used to manufacture products with exacting standards, including automobiles, semiconductor chips, mobile phones, tablets, and PCs. We are a world's leading optical component and module supplier.

Kilowatt Fiber Lasers are used for laser cutting, welding, heat treating, and additive material applications. Ultrafast Industrial Lasers are ideal for a wide variety of micromachining applications including display processing, PCB production, semiconductor processing, and medical device manufacturing.

These laser products require laser fibers for their operation, which are both produced in-house by LUMENTUM and outsourced.

Figure 2 - LUMENTUM CORELIGHT fiber laser product

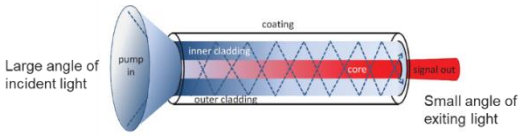

Figure 1 - Light passing through a laser fiber

Laser fibers and optical coatings

The main function of laser fibers is to reduce the exit angle of light, and therefore increase brightness. In laser fibers, two layers of polymeric optical coatings are applied:

- Primary coating – softer, performs an optical function of total internal reflection (has low refractive index)
- Secondary coating – harder, used for physical protective function.

Primary coatings with **low refractive index** are used in so-called double-clad and triple-clad fibers which represent the universal design solution for high-power lasers and amplifiers since 1988[1] (link to encyclopaedic explanation).

The refractive index (RI) of a polymer is the ratio of the speed of light in a vacuum to the speed of light through the polymer.

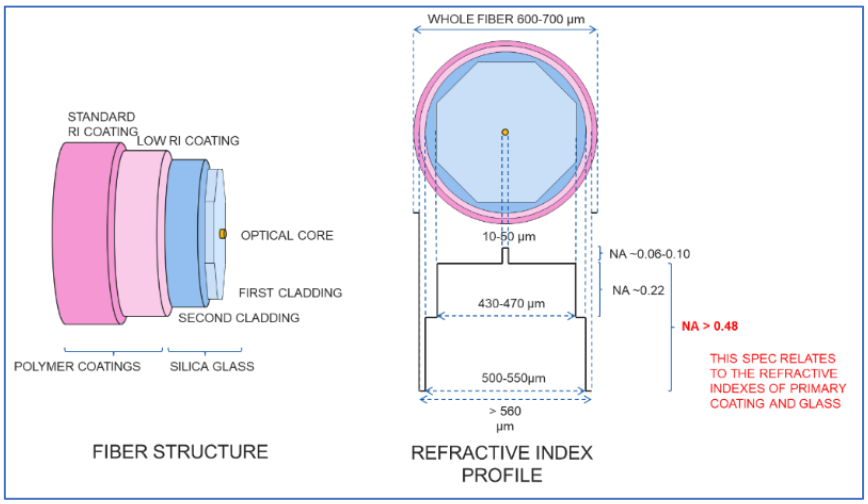

Figure 3 - Fiber structure and refractive index profile

Functionality of fluoropolymer coating with low refractive index

- For laser fiber products, the refractive index of the primary coating needs to be lower than 1.38.
- Coatings with higher refractive indexes are not suitable as light will not be guided as intended, leading to excessive energy dissipation, overheating and mechanical failure of the fiber.
- To achieve a refractive index lower than 1.38, specialty fluorinated polymers (PFAS) are required.
- Other non-PFAS polymers cannot deliver a refractive index lower than 1.38.

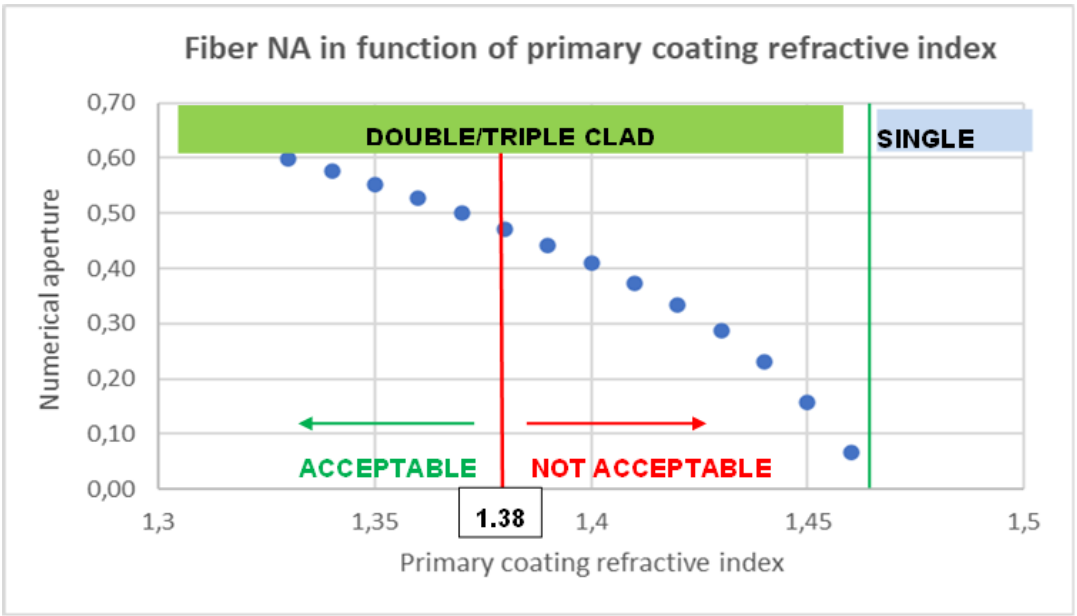

Figure 4 - For laser fiber operation, the fiber must accept a large angle of incident light (acceptance cone), which is defined by its Numerical Aperture (NA). For the laser fiber to work as intended, NA needs to be higher than 0.48, and the refractive index of the primary coating needs to be lower than 1.38.

Absence of suitable alternatives

Currently there are no alternative materials available on the market to replace low refractive index fluoropolymer coatings for laser fibers. Other common polymer materials are not suitable for fiber laser application, as a refractive index below 1.38 cannot be achieved.

Fluorinated	Epoxy	POM	Acrylics	PP	PUR	PE	UP
1.31-1.4	1.45-1.6	1.48-1.51	1.49-1.57	1.5-1.51	1.5-1.6	1.51-1.54	1.52-1.54

PA	PVC	PS	PET	PC	Sulfone	PEEK	PEI
1.53-1.54	1.53-1.55	1.55-1.59	1.55-1.64	1.58-1.6	1.63-1.65	1.65-1.77	1.66-1.67

Figure 5 - Refractive Index of Fluoropolymers vs Other Polymers[2]

Research carried-out by LUMENTUM, and feedback from LUMENTUM's supply chain confirms that alternative materials are not available.

- Feedback from a key manufacturer and supplier of coatings: *It is not possible to develop an alternative with such index without PFAS. Without using PFAS, the lowest possible index is 1.41.* Refer to their consultation application reference 5d11eae4-2d11-4b4c-9a24-c50d348bc1a0.
- Feedback from another supplier of coatings: *[product name deleted] is expected to be affected by the proposed restriction, and so far, there is no initiative to make a non-PFAS alternative for EU.*
- Feedback from the Faculty of Polymer Technology in Slovenia (LUMENTUM's research partner): *no alternative material was recognized to achieve the critical properties (RI<1.4) we require for our fibers to function.*

Impacts of banning fluoropolymers in low refractive index coatings

Fluoropolymers, in the form of low refractive index polymer coatings, are indispensable for laser fibers and their application in lasers.

Currently there are no known suitable alternative materials on the market, hence banning the use of fluoropolymers would severely impact LUMENTUM.

LUMENTUM's production lines of laser fibers and kilowatt lasers would have to stop production, resulting in significant loss of revenue and personnel. In addition, some products currently being developed for the Ultrafast Lasers product line would have to be abandoned, resulting in wastage of material resources and time already invested.

Kilowatt Fiber Lasers are becoming the industry standard for metal cutting applications, displacing CO2 laser and plasma cutting systems, in large part due to their environmental advantages. They are vastly more efficient in terms of electrical usage and reduce toxic waste created during the process. The industry could technically revert to older technology, but it would be a major step backward in terms of cost, quality, and environmental impact.

Revenue impact

The expected revenue loss assuming a PFAS ban implementation in 2026 is:

- To **LUMENTUM**:

  In FY23, annual revenue from LUMENTUM lasers was **$209M**. Significant percentage of the revenue would be impacted.

- To LUMENTUM **customers:**

  The estimated impact to LUMENTUM's customers using LUMENTUM lasers in their products (laser cutting and welding machines): **$1.8B per year**.

- To **end customers:**

  The estimated impact to end customers using laser cutting and welding machines with LUMENTUM lasers in the manufacturing processes: **$7B per year**.

Personnel impact

Hundreds of LUMENTUM employees would be impacted worldwide, including about 100 employees working in the laser fiber manufacturing in the EU.

Risk of fluoropolymers to the environment

Fluoropolymers have been categorized as PFAS[3] when based solely on their molecular structure. However, their environmental and toxicological profiles are distinctly different from the majority of other lower molecular weight PFAS.

In general, the properties of many fluoropolymers (fluoroplastics and fluoroelastomers) are such that they do not display the environmental and toxicological profiles associated with some PFAS that could be considered of concern.

Specifically, recent studies[4,5] have shown that 16 unique families of commercially popular fluoropolymers meet the OECD Polymer of Low Concern criteria[6]. They are chemically stable, non-toxic, non-bioavailable, non-water soluble and non-mobile materials and they are deemed to have no significant environmental and human health impacts.

On-site management of the fluoropolymer coating material

Due to the controls and processes in place and the low quantities handled at LUMENTUM manufacturing facilities, the risk to human health and the environment of using fluoropolymer coating materials is deemed low.

Storage and handling

- The amount of coating material stored and handled at any one time is very low: 500 g bottle.
- The coating material is stored in chemical storage cupboards and is handled in a catch basin inside a fume hood.
- Employees working within the area are trained on how to deal with spillages, and there is also an Emergency Response team on site.
- In case of spillage the coating material cannot enter the sewer, as the area where the chemicals are used does not have direct discharge into the sewer.
- Access to the chemical storage area is limited to authorised staff.

Application of coating to the fibers

The coating material is applied onto the glass core of the optical fiber via a semi-automated process and requires specialised machinery and operators. To enter the fiber draw production area, operators must wear a clean-room gown, laboratory footwear, goggles, and gloves.

The coating material is fed to a machine via a sealed pressurised container, and when topping-up is required, the container is taken to the fume hood to be filled.

Usage amounts

- The content of low refractive index fluoropolymer coating in a laser fiber is approximately 96g per km of fiber.
- The yearly consumption of low refractive index fluoropolymer coating used in production and R&D is approximately 31 kg.
- For a complete laser unit, this equates to approximately 3g of low refractive index fluoropolymer coating.
- Optical fibers have a long lifespan, estimated to be higher than 10 years when in use.

Waste disposal

Waste coating material is disposed-of as hazardous waste using an authorized external waste company. Scrap optical fibers are disposed-of to recycling.

References

[1] Source: *E. Snitzer et al., *"Double-clad, offset-core Nd fiber laser"* (first report of cladding pumping, Proc. Conf. Optical Fiber Sensors, Postdeadline paper PD5 (1988)

[2] Source: Refractive Index of Plastic Materials (Low & Ultra-Low Refraction) (specialchem.com)

[3] Reconciling Terminology of the Universe of Per- and Polyfluoroalkyl Substances: Recommendations and Practical Guidance Series on Risk Management No.61, 9 July 2021. https://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=ENV/CBC/MONO(2021)25&docLanguage=En

[4] A critical review of the application of polymer of low concern regulatory criteria to fluoropolymers II: Fluoroplastics and Fluoroelastomers, Stephen H. Korzeniowski et al, 2022. https://setac.onlinelibrary.wiley.com/doi/full/10.1002/ieam.4646?af=R

[5] A critical review of the application of polymer of low concern and regulatory criteria to fluoropolymers, Barbara Henry et al, 2018. https://setac.onlinelibrary.wiley.com/doi/full/10.1002/ieam.4035

[6] Data Analysis of the identification of correlations between polymer characteristics and potential for health or ecotoxicological concern, OECD 2009. https://www.oecd.org/env/ehs/risk-assessment/42081261.pdf