Exemption Request Form

Date of submission: [*date TBC*]

1. Name and contact details

1) Name and contact details of applicant:

Company:	**Coherent Inc.**	Tel.:	+1 408 764 4650
Name:	Paul Ginouves	E-Mail:	paul.ginouves@coherent.com
Function:	General Manager	Address:	5100 Patrick Henry Dr. Santa Clara, CA 95054

2) Name and contact details of responsible person for this application (if different from above):

Company:	Same	Tel.:	[*TBC*]
Name:	[*TBC*]	E-Mail:	[*TBC*]
Function:	[*TBC*]	Address:	[*TBC*]

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2. Reason for application:

Please indicate where relevant:

☐ Request for new exemption in: **N/A**

☐ Request for amendment of existing exemption in: **N/A**

X Request for extension of existing exemption nr. 32 of Annex III of Directive 2011/65/EU ("the RoHS II Directive), "Lead oxide (PbO) in seal frit used for making window assemblies for Argon and Krypton laser tubes"

☐ Request for deletion of existing exemption in: **N/A**

☐ Provision of information referring to an existing specific exemption in: **N/A**

☐ Annex III ☐ Annex IV

No. of exemption in Annex III or IV where applicable:	**nr. 32 of Annex III**
Proposed or existing wording:	**Request for extension of existing exemption "Lead oxide in seal frit used for making window assemblies for Argon and Krypton laser tubes"**
Duration where applicable:	**Renewal of the 5-year validity period as from 21 July 2016**

☐ Other: **N/A**

3. Summary of the exemption request / revocation request

This request relates to a renewal of the exemption nr. 32 of Annex III of the RoHS II Directive, “Lead oxide in seal frit used for making window assemblies for Argon and Krypton laser tubes”, which is valid until 21 July 2016. In accordance with article 5.5 of the RoHS II Directive, this application for the renewal of exemption nr. 32 is made no later than 18 months before the exemption expires.

4. Technical description of the exemption request / revocation request

(A) Description of the concerned application:

1. To which EEE is the exemption request/information relevant?

Name of applications or products:

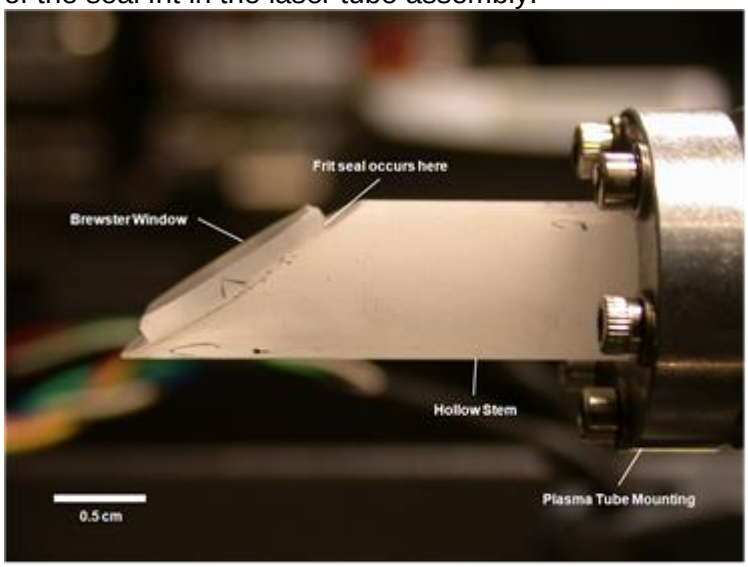
Glass frit is used by Coherent Inc. as a vacuum seal in the manufacture of Argon and Krypton ion laser tubes.

Argon and Krypton ion lasers in use in the EU today are primarily for scientific and light industrial applications such as:

- **Spectroscopy** (e.g., examination of molecules or atoms by measuring effects of laser beam exposure);
- **Microscopy** (e.g., magnification of samples and objects using laser as light source; non-medical uses include examination of geologic materials);
- **Holography** (e.g., using lasers to record and/or view optically stored information for applications such as data storage, security, art, engineering and communications)

The lead oxide in the seal frit is located in a Brewster window assembly, ie an optomechanical assembly that provides a vacuum-tight seal and is optically transparent to the laser radiation. It is a critical optical interface that significantly affects the performance of the laser. A plasma tube can have either one or two of these assemblies based on its type. Greater than 90% of the seal frit is contained between two planes of crystalline quartz. Just as Coherent Inc. uses the lead frit to create a hermetic seal, the frit itself becomes isolated from the

environment between these two planes. The picture below shows the location of the seal frit in the laser tube assembly.



a. List of relevant categories: (mark more than one where applicable)

☐ 1	☐ 7
☐ 2	☐ 8
☐ 3	☐ 9
☐ 4	☐ 10
☐ 5	☐ 11

x 6

b. Please specify if application is in use in other categories to which the exemption request does not refer: No

c. Please specify for equipment of category 8 and 9:

The requested exemption will be applied in

☐ monitoring and control instruments in industry

☐ in-vitro diagnostics

☐ other medical devices or other monitoring and control instruments than those in industry

2. Which of the six substances is in use in the application/product?

   (Indicate more than one where applicable)

   x Pb ☐ Cd ☐ Hg ☐ Cr-VI ☐ PBB ☐ PBDE

   (PbO)

3. Function of the substance:

Lead oxide glass frit has been used as a seal material in ion lasers since 1975. These ion lasers are an important product line for Coherent Inc., which has been producing these products since 1968. Ion lasers are unique in that they generate a variety of wavelengths in the ultraviolet, visible and infrared regions of the electromagnetic spectrum. These lasers are capable of producing ultrapure spatial and temporal output, and find multiple uses in scientific and commercial applications.

4. Content of substance in homogeneous material (%weight):

   70%

5. Amount of substance entering the EU market annually through application for which the exemption is requested:

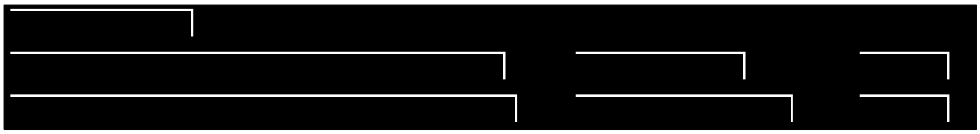
Coherent Inc.'s most recent (CY 2014) annual shipments of replacement plasma tubes, or new systems containing plasma tubes, in all non-exempt applications, EU-wide, is: 0.641g.

The number of ion lasers in use for all applications is flat to declining, both in the EU and globally. There is no potential for emerging applications that would employ ion laser technology, and thus, the amount of Pb introduced per annum would be generally flat to declining in subsequent years.

Aggregate Pb in the EU as a result of Pb in Brewster window assemblies is remaining relatively constant, as the vast majority of plasma tubes are introduced as replacements for existing installations, and the defective tube is removed for environmentally-responsible recycling and disposal.

Further, tubes or systems sold to integrators were subsequently exported from the EU, and therefore do not contribute to the aggregate.

CY 2014:



TOTAL: 0.641g

Of this, only one tube was known to be incremental. All others were replacements, or subsequently exported.

6. Name of material/component:

Lead oxide is the hazardous substance; it represents 70% of the material content of the frit glass. Glass frit is used as a vacuum seal in the manufacture of Ar and Kr Ion laser tubes.

The balance is a Zinc compound and Zirconium silicate. The homogenous material weight of one seal is 15 mg, of which 10.5 mg is Lead oxide. There are 1 or 2 seals per device. Annual shipments account for less than 5 grams of Lead oxide total (including both exempt and non-exempt applications).

7. Environmental Assessment:

In Coherent Inc.'s case, the environmental, health and safety impacts of continuing the exemption are minimal, primarily because:

- Less than 1.0 gram of lead annually will be introduced into the EU for non-exempt applications;
- Coherent Inc.'s ion lasers are deeply embedded within other pieces of equipment and therefore pose little or no risk of exposure to the lead-containing materials. Further, once integrated into a Brewster window assembly, PbO is sequestered in what is essentially a monolithic assembly which is indivisible at temperatures below 425 degrees C.; and
- Coherent Inc.'s plasma tubes are recovered to a Coherent Inc. subsidiary or the production facility in California where they are appropriately recovered and disposed of, so they will not create waste in the EU. Annual incremental increase in aggregate PB in the EU as a result of plasma tubes is negligible.

Conversely, the negative environmental, health and safety impacts that would result from substitution would be substantial, including:

- decreased reliability of the seal, which could cause the lasers to fail, resulting in an unacceptable risk to equipment manufacturers and end users;
- increased consumption of energy required to transport replacement tubes because of the decreased reliability;
- creation of waste through lower yields; and
- increased consumption of energy required for long-term testing and use of substitutes.

LCA: ☐ Yes
X No

(B) In which material and/or component is the RoHS-regulated substance used, for which you request the exemption or its revocation? What is the function of this material or component?

Coherent uses lead oxide to bond the front and rear crystalline quartz windows (ie Brewster windows) to crystalline quartz stems that are themselves vacuum sealed to the laser tube assembly using Indium. Windows are the critical optical interface, where optical absorption, scatter and distortion ultimately determine the performance of the laser. Crystalline quartz is used because of its resistance to darkening caused by sub-200nm radiation emanating from the electric arc discharge in the laser tube.

(C) What are the particular characteristics and functions of the RoHS-regulated substance that require its use in this material or component?

The reason that lead oxide is used in the seal frit is that the application requires a permanent, hard, vacuum impermeable seal that will tolerate vacuum bakeout temperatures but has a liquidus-solidus temperature that will not result in unacceptable mechanical strain at the operating temperature. Part geometries are adjusted within the particular constraints of the device in order to minimize the demands placed on the seal.

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5. Information on Possible preparation for reuse or recycling of waste from EEE and on provisions for appropriate treatment of waste

1) Please indicate if a closed loop system exist for EEE waste of application exists and provide information of its characteristics (method of collection to ensure closed loop, method of treatment, etc.)

In accordance with Coherent Inc.'s normal practices and procedures, Coherent Inc. recovers all expended plasma tubes to a subsidiary of Coherent Inc. or its production facility in California (USA) for environmentally responsible recycling and/or disposal. Therefore, even the minimal amount of lead oxide contained in the Argon and Krypton laser tubes does not become waste within the EU.

2) Please indicate where relevant:

X☐ Article is collected and sent without dismantling for recycling

X☐ Article is collected and completely refurbished for reuse

☐ Article is collected and dismantled:

- ☐ The following parts are refurbished for use as spare parts: _____
- ☐ The following parts are subsequently recycled: _____

☐ Article cannot be recycled and is therefore:

- ☐ Sent for energy return
- ☐ Landfilled

3) Please provide information concerning the amount (weight) of RoHS substance present in EEE waste accumulates per annum:

X☐ In articles which are refurbished — Negligible, return material comes back to US

X In articles which are recycled — Negligible, return material comes back to US

☐ In articles which are sent for energy return — _____

☐ In articles which are landfilled — _____

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6. Analysis of possible alternative substances

(A) Please provide information if possible alternative applications or alternatives for use of RoHS substances in application exist. Please elaborate analysis on a life-cycle basis, including where available information about independent research, peer-review studies development activities undertaken

Despite years of on-going development, Coherent Inc. currently has no feasible substitute for the use of lead oxide in Ion laser tubes. Due to intractable constraints on the manufacturing process temperature and on the properties and composition of the window bonds, it is technically and scientifically impracticable to exclude lead-containing seal frit from the manufacture of Coherent Inc.'s products. The required use of a crystalline material, combined with the geometry of these windows, i.e., mounted at an acute angle with respect to the laser beam axis, in addition to the vacuum and absolute cleanliness requirements, makes the use of other approaches a practical impossibility. Use of alternative types of materials would compromise the integrity of the seal, causing the laser to fail. The windows are a critical optical interface for these devices and significant effort and expense is already required in producing these sub-assemblies.

Even though alternative lead-free frit materials exist (such as bismuth- or phosphorous-based glasses), they are still in the exploratory stages and have not been well developed in industry; Coherent Inc. plans to experiment with the lowest working temperature examples (125˚C higher than lead oxide), but there are a number of technical and scientific processes that render their use impracticable at this time. At Coherent Inc. we have approximately 30 years of continuing development on these issues, and during that time we have not discovered a viable alternative to the use of lead oxide based frit glass. The quantity of lead oxide in each seal is 10 mg and the total amount in our annual shipments (including both exempt and non-exempt applications) into the EU is less than 5 grams.

(B) Please provide information and data to establish reliability of possible substitutes of application and of RoHS materials in application

Bismuth- or phosphorous-based glasses may potentially offer promise as a substitute, but they are **not sufficiently developed technically or commercially to be viable** to Coherent Inc.; there is no experience or working

history in industry with those materials and Coherent Inc. does not believe they satisfy the exacting technical requirements to form the window bonds.

For a number of reasons, Coherent Inc. believes there are a number of fundamental unresolved difficulties with respect to the viability of lead-free alternatives for the fabrication of Brewster window assemblies:

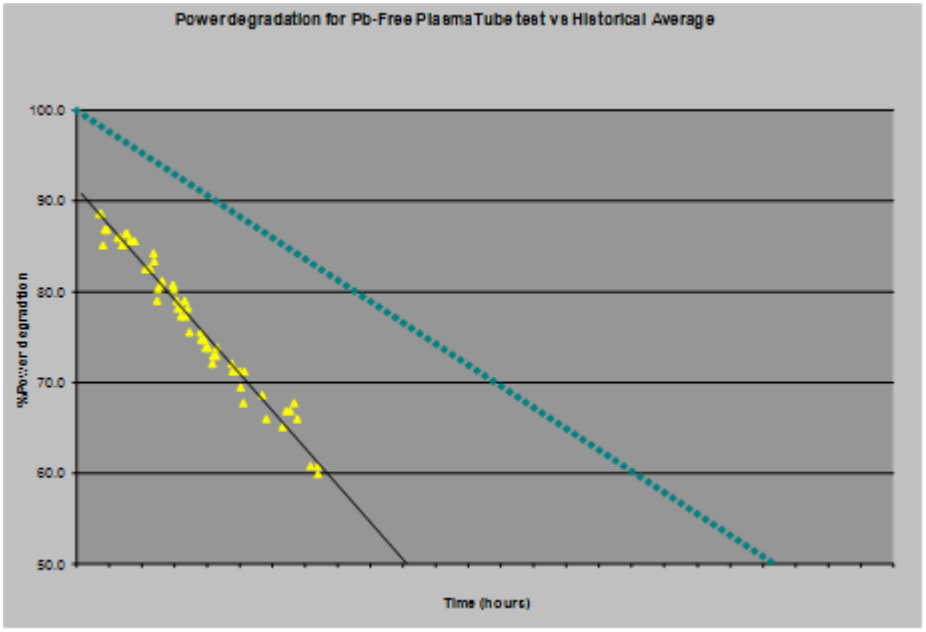
1. **Yield**: The process of record is multifaceted and complex. It has evolved incrementally over 40 years. There are extraordinarily stringent requirements for mechanical and optical performance. Despite Coherent Inc.'s experience with the established process, yields are only borderline acceptable. Any change to the established process will drive yield lower. No lead-free frit exists which would allow Coherent Inc. to utilize its established processing envelope. Alternative frit materials have melting temperatures of 550°C. This is 125°C higher than the material used in the process of record. These higher temperatures will place extreme stresses on both raw materials in the assembly, and the production tooling. A reduction in yield will severely compromise our ability to provide sufficient product for mission-critical applications in the semiconductor and microelectronics markets.

2. **Performance**: The performance of Coherent Inc.'s plasma tubes are determined to a significant extent by their capability to resist optical degradation by vacuum ultraviolet (VUV) radiation emanating from the gas plasma. A proprietary optical coating on the vacuum side of the Brewster window confers this distinguishing characteristic. Deposition of this unique optical coating on the Brewster window occurs prior to fritting the window to the stem. The dimensions of the assembly and limitations of the coating process preclude the application of the coating after the window fritting process. Because of this process limitation, the coating must endure the high temperatures required to bring the frit to liquid state. The higher temperatures required by the lead-free material will compromise the integrity of this coating. Manifestations of this degradation are yield loss and premature field failure. Coherent Inc. is not aware of a coating that provides the required performance and confers resistance to the higher processing temperatures.

3. **Usable lifetime**: In highly accelerated testing, lead-free alternatives performed very poorly when compared to the process of record. Figure 1 is illustrative of the significant differences Coherent Inc. encountered. The yellow data points represent the lead-free test. The blue line is the current process. (Due to the sensitive nature of the data, x-axis (hours) values have been removed). In the lead-free sample, two things are remarkable: ie (i) there was

an output power (usable light) reduction at the onset, and (ii) it takes less than half the time to a 50% drop in output. The 10% initial output loss notwithstanding, just a 10% reduction in performance would be significant to our end-users. A 50% reduction would be catastrophic. Coherent Inc. has neither a clear technology path nor a projected timetable that would allow us to mitigate performance gaps of this magnitude.

Figure 1.



7. Proposed actions to develop possible substitutes

(A) Please provide information if actions have been taken to develop further possible alternatives for the application or alternatives for RoHS substances in the application.

N/A – see section above under 6(B)

(B) Please elaborate what stages are necessary for establishment of possible substitute and respective timeframe needed for completion of such stages.

N/A – see section above under 6(B)

8. Justification according to Article 5(1)(a):

(A) Links to REACH: (substance + substitute)

1) Do any of the following provisions apply to the application described under (A) and (C)?

☐ Authorisation

X SVHC

X Candidate list (ECHA decision ED/169/2012 dated 18 December 2012)

X Proposal inclusion Annex XIV

☐ Annex XIV

☐ Restriction

☐ Annex XVII

☐ Registry of intentions

x Registration

2) Provide REACH-relevant information received through the supply chain.
Name of document: _____

(B) Elimination/substitution:

1. Can the substance named under 4.(A)1 be eliminated?

☐ Yes. Consequences? _____

X No. Justification:

☐ The elimination of the lead by substituting other materials (e.g., Bismuth-based frit materials) continues to be **technically and scientifically impracticable** because these substitutes are not able to satisfy the stringent requirements for optical performance in the relevant equipment. Further, lead-free alternatives not only produce poor yields, but also create untenable risk for our commercial customers that rely on performance statistics accumulated over many years of continuous operation;

☐ The elimination of the lead via design changes (e.g., optical contacting) continues to be technically and scientifically impracticable due to scale of implementation required for production of Brewster window assemblies; and

☐ The **negative environmental, health and consumer safety impacts** caused by substitution are likely to outweigh the environmental, health or consumer safety benefits thereof because the environmental impact is minimal (i.e., less than 1.0 g of lead annually in the EU for non-exempt applications, most of which is recovered by Coherent Inc. pursuant to protocol and does not become waste in the EU). The expected negative impact to plasma tube lifetime resulting from the elimination of lead would: 1) necessitate more frequent tube exchanges in the field and a cause

significantly higher overall environmental impact due to the increased waste stream; 2) create higher carbon emissions from the increased logistics required for more frequent replacements; and 3) increase concomitant, and potentially hazardous, waste from discarded material in end-user industrial processes which have been adversely affected by premature failure.

2. Can the substance named under 4.(A)1 be substituted?

☐ Yes.

☐ Design changes:
☐ Other materials:
☐ Other substance:

X No.

Justification:

It remains technically and scientifically impracticable to substitute the use of lead oxide in the seal frit. Since 2006, Coherent Inc. has continued to research the use of substitutes, such as Bismuth-based frit, and – based on this research – it has concluded that there is no feasible substitute for the following reasons:

(a) **Higher window temperatures result from lead-free fritted windows**. Window temperatures are a surrogate measurement of optical absorption. High window temperatures are indicative of contamination or bulk material change. This change may have as the root cause (i) the composition of the lead-free frit, (ii) much higher temperatures (125 degrees C over the lead material) required for liquid phase, or (iii) a combination of these factors and yet other undetermined factors. Higher window temperatures—and therefore higher optical absorption—mean greater optical loss and degradation of transverse emission mode (the intensity profile of the beam across its optical axis). Coherent Inc.'s commercial customers have invested millions of dollars in engineering tools with extremely fine tolerances to critical optical parameters, and its lasers must provide a highly characterized beam of light. Optics assemblies in these tools are not adjustable beyond a very narrow acceptance window. The changes to optical absorption that would result from introducing lead-free frit go beyond these parameters and would result in unacceptable risk to the end users.

(b) **Optical distortion due to material strain.** The lead oxide frit Coherent Inc. uses today is critically matched to the crystalline quartz of the window and stem with respect to coefficient of thermal expansion (**CTE**)—it is this vital quality that is not achievable with lead-free frit.

Mismatched CTE creates stress in the completed assembly that introduces optical distortion and positional inconsistency. In other words, the lead is present to lower the melting point of the frit; other materials we have tested require higher melting points, and in turn when they cool back down, the window does not come to the correct angle (requiring the whole assembly to be scrapped).

Poor yield results from substitutes relative to lead frit. Coherent INc. now has almost four decades of experience with lead frit bonding techniques. Its yield with these techniques is high, typically 90% or more.

The much higher melting points of lead-free frit creates a multitude of yield issues, including material strain problems that would force Coherent Inc. to scrap a much higher percentage of window assemblies. This would have a negative environmental impact as it would create additional waste during the production process.

More recently, Coherent Inc. investigated a Bismuth-based alternative frit. In order to comprehensively test this alternative, it was necessary to build entire assemblies and run them through accelerated life tests. It then examined the data both in relation to window temperatures and degradation of the windows. In interpreting the data, temperatures are relevant because any contamination in the window can cause it to absorb more light, heat up and essentially act like a lens. This introduces differences in how the laser beam behaves and looks to the observer.

Coherent Inc.'s results from testing with this product were **not acceptable** due to:

(a) Higher window temperatures, between +10 and +60 degrees Celsius versus normal for the same tube type;

(b) A steeper than normal degradation curve which would compromise end-user lifetime on the order of 20% to 25%; and

(c) Increased difficulty in using the material. Use of lead-free material would necessitate substantial changes to Coherent Inc.'s processing protocol that would require years of R&D and testing to confirm, assuming it could conquer the aforementioned challenges.

3. Give details on the reliability of substitutes (technical data + information): **see above under section 8 (B) 1 and 2.**

4. Describe environmental assessment of substance from 4.(A)1 and possible substitutes with regard to
   1) Environmental impacts: **see above under section 8 (B) 1**.
   2) Health impacts: **see above under section 8 (B) 1**.
   3) Consumer safety impacts: **see above under section 8 (B) 1.**

⇨ Do impacts of substitution outweigh benefits thereof?
Please provide third-party verified assessment on this: _____

JDSU Uniphase is preparing a separate submission for continuation of the Exemption. They will provide data on higher melting point of alternate frit material damaging the Brewster window.

(C) Availability of substitutes:

a) Describe supply sources for substitutes: **N/A**

b) Have you encountered problems with the availability? Describe: **N/A**

c) Do you consider the price of the substitute to be a problem for the availability? **N/A**

☐ Yes ☐ No

d) What conditions need to be fulfilled to ensure the availability?

N/A - Coherent does not have a feasible substitute / alternative, and at this point there are no clear benefits to the environment of using alternative substances. Significant disadvantages may result from the use of substitutes, especially with respect to decreased reliability of the products.

Lead oxide used in glass frit is the only material practically available for this application, for a number of reasons. Crystalline quartz is the only material that adequately resists DUV induced absorption. However, it has certain material characteristics that must be considered. The material is birefringent and, as a consequence, orientation of the crystal axis is required. The coefficient of thermal expansion is different for each of the crystal axes, necessitating the same crystal orientation for the window and for its stem. A precision alignment of the window to its stem is required prior to bonding. The optimum choice of a particular frit is determined by the melt and freeze temperatures and the thermal expansion coefficient. The wetting and flow characteristics are very good and the bonding process reproducible. The properties of the frit make it ideal for high vacuum bonds; namely, it has an extremely low vapor pressure and it is leak-free to the He detection limits, non-hydroscopic and impermeable. PbO glass frit has been highly developed and extensively used in the tube industry. Use of a different material would compromise the integrity of the vacuum seal and likely

cause malfunctions in the products. No other materials have been commercially developed to anywhere near the same extent.

(D) Socio-economic impact of substitution: N/A

⇨ What kind of economic effects do you consider related to substitution?

- ☐ Increase in direct production costs
- ☐ Increase in fixed costs
- ☐ Increase in overhead
- ☐ Possible social impacts within the EU
- ☐ Possible social impacts external to the EU
- ☐ Other: _____

⇨ Provide sufficient evidence (third-party verified) to support your statement: _____

9. Other relevant information

Please provide additional relevant information to further establish the necessity of your request:

Solid state laser technologies are replacing the type of laser that uses these seals and new system shipments have been in steady decline for 5 years. The use of Argon and Krypton lasers will persist in those applications only where their unique multiwavelength performance is a necessity, ultimately becoming more of a specialty product. Nearly 100% of the laser tubes shipped in the coming years will be in support of the current installed base for which compliance is not required and for other uses that are currently exempt from the RoHS II Directive requirements;

For a technical drawing illustrating the laser tube assembly, please to the attachment A to this request.

10. Information that should be regarded as proprietary

Please state clearly whether any of the above information should be regarded to as proprietary information. If so, please provide verifiable justification:

_____

Shipment information for plasma tube in 2014. Attachment A, Detailed drawing of Brewster window assembly.