Superior Reliability & Performance

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Dr.-Ing. Otmar Deubzer
Senior Scientist
Fraunhofer Institut Zuverlässigkeit und Mikrointegration
Abt. Environmental and Reliability Engineering
Gustav-Meyer-Allee 25, 13355 Berlin

Dear Dr. Deubzer,

Herein find additional information on Coherent's request for continuation of RoHS Exemption 32.

The questions put forward are:

1) Coherent explains in its exemption request that solid state laser technologies are replacing the type of laser that requires the above requested exemption, and new system shipments have been in steady decline for 5 years. 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. The use of Argon and Krypton lasers will persist in those applications only where their unique multi-wavelength performance is a necessity.
   a) Can the exemption be restricted to those applications that require the unique properties of ion lasers? Devices with laser tubes using the exemption in its current scope and wording could still be repaired and upgraded provided they were made available on the EU market prior to the date where the general exemption expires and the new, scope-restricted one would be enacted.

   b) What are the applications that depend on the unique properties of ion lasers?

2) Please provide an overview on all potential lead-free substitutes for PbO seal frits in argon and krypton lasers including the tests you conducted and the main findings of those tests.

3) Please resubmit your exemption request including a summary summarizing all relevant aspects of your exemption request.

Some historical information might be helpful here. The use of ion lasers has been in steady and quite significant decline since well before the inception of RoHS. New installations of ion lasers came to a zenith in 2000, in a market run-up that ran in lockstep with the dot-com bubble. Many ion laser markets experienced unprecedented growth during this period. In the telecom market, expansive growth drove seemingly unlimited budgets and the need for sophisticated laser-driven processing equipment. Other

5100 Patrick Henry Drive
Santa Clara
California 95054
Phone (408) 764-4000
Fax (408) 764-4800

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markets, such as optical pumping of ultrafast lasers, bioinstrumentation, and DVD mastering, to name several, grew with the burgeoning economy. When the bubble finally burst after 2000, some markets—such as fiber Bragg grating manufacturing—collapsed rapidly and nearly completely. The aforementioned applications of pumping, instrumentation, and disc mastering declined with changing paradigms, declining funds, and alternate laser technologies.

It is safe to say that ion lasers are in use today only in those applications that cannot use a substitute, based on one or more of the following reasons:

- A requirement for a specific, process-driven wavelength
- A requirement for continuous wave radiation
- A requirement for discrete tuning at a number of visible and/or UV wavelengths
- A requirement for single longitudinal mode
- A requirement for higher output power than is available in a substitute
- A requirement for deep UV, 257 nm and less
- A requirement for low output noise which is not available in an alternate
- A requirement for transverse mode quality that is not available in an alternate
- A requirement for known cost in an established market—in other words, the alternative is more than the market will bear
- A requirement for a copy-exactly process where the cost of risk retirement for any substitute would be prohibitive

Applications that fit into this category are:

- Photomask direct imaging
- Flat panel display direct imaging
- Photomask inspection
- Patterned wafer inspection
- Spectroscopy
- Holography
- Some types of computer-to-plate imaging
- Some types of particle imaging velocimetry

(Please note that these lists are not comprehensive, but representative.)

There is no growth market today for ion lasers of any type. Many more ion lasers come out of service each year than go into service. The global market for ion lasers with output more than 500 mW is less than 75 per year, with nearly all of the demand in Asia. There is no market scenario, real or imagined, which will alter this trajectory.

Coherent's ion laser business primarily supports legacy applications in the semiconductor and microelectronic industries. We capture about 90% of our total business volume in this segment. Coherent serves this segment with a depot repair strategy that ensures recovery of all plasma tubes for disposal in an environmentally responsible manner, irrespective of geography. Our collection point for plasma tubes is Santa Clara, California. We have two ion laser depots, one in Santa Clara, the other in Tokyo, Japan. Approximately 70% of the business turnover is from installations in Asia.

New installations in the EU are rare, and as is the case globally, many more ion lasers come out of service each year than are installed in the EU. In the full CY 2014, Coherent ion lasers introduced less than 1 g Pb in all shipments to the EU, new or service, exempt, or non-exempt. Only 0.020 g was incremental during that same period. We detailed this in our most recent submission for extension.

As has already been said, the amount of new ion laser installations will continue to drop worldwide. Every year, Pb mass shipped globally under Exemption 32 will decrease. Whether total introduction, or incremental introduction, it would not be a difficult case to make that there is a miniscule contribution by ion lasers. Atmospheric Pb contamination in the EU stood at 1200 tons/year in 2012, for industrial sources alone. Other sources such as transport, commercial, institutional, and household fuel combustion accounted for at least as much on top of that. ("Air Quality in Europe, 2014 Report", EEA Report No5/2014, ESSN 1977-8499).

Ion lasers are by their very nature the technology of last resort. They are most certainly powerful tools, but the fact remains that they are dinosaurs of the laser industry. They are bulky, inefficient at conversion of electrical energy to light output, and require dedicated infrastructure. Further, because they are relatively complex electro-optical devices, they typically require specialized training to install, maintain, and operate. That they remain in use today is a testament not only to their unique characteristics, and to the variety of performance improvements incorporated over 4 decades of use in science and industry, but more importantly, the lack of a complete suite of alternative technologies that sufficiently supplant the ion laser solution.

You have posed the thoughtful question whether or not Exemption 32 could be limited in scope to only those applications where there is no alternative. I would say that this is virtually already the case, and it has been that way for some time. People only choose to purchase an ion laser when there is no real practical substitute. Likewise, they only choose to continue to use an existing ion laser where the same such characteristics prevail. However, to suggest a change to the language of Exemption 32 to allow it in applications only where there is no alternative would be to suggest that there might be some burden of proof to apply. In such a case, how would that burden be satisfied, and by whom?

Back to the matter at hand: Pb in Brewster window assemblies. A Brewster window satisfies two key functions in an ion laser: 1. It provides a permanent, hermetic high vacuum seal for the Argon or Krypton gas in the plasma tube; and, 2. It provides a loss element for a single axis of light polarization. The assembly must be able to function over many years of operation. The Brewster window is an otherwise inert optical element that should introduce no laser beam degradation, perturbation, or internal contamination to the hermetic plasma tube. Coherent fabricates Brewster window and mounting stem from crystalline quartz substrates, which matches their coefficient of thermal expansion and minimizes stress on the assembly. Any curvature of the Brewster window will cause the plasma tube to fail. Internal contamination of the Brewster window will cause the plasma tube to fail. Further, Coherent Brewster windows have an optical coating to resist the vacuum UV radiation produced by the inert gas plasma. This coating must be on the inner surface of the Brewster window, and this coating is sensitive to perturbation from contamination or excessive heat.

On the matter of Pb frit alternatives, Coherent has evaluated adhesives, optical contacting, Bismuth-based frit, and Indium. All of these alternatives have proven unsuitable for use for a variety of reasons.

1. We know of no adhesive that would provide a hermetic, CTE matched seal between the Brewster window and the stem without compromising the internal optical surface of the Brewster window. Early ion lasers did use epoxy in the manufacture of the plasma tube, but keep in mind that early plasma tubes only performed for several hundred hours before failing. Plasma tubes have not used adhesives in decades.
2. Optical contacting necessitates polishing to less than one nanometer precision, perfectly conformal—in this case, planar, and perfectly clean and free of particulate. Although practical for low-volume specialty items such as cubes or prisms, it is not practical for an assembly such as this. A single speck of dust is yield loss. We have never been able to make this technique work on a production scale. This technique is neither practical nor cost-effective.
3. Bismuth-based frit, while otherwise, the best alternative for our use, has one Achilles' heel—the process is more than 100-degrees C higher than the Pb frit. All of our testing in the past has yielded very high degradation rates for plasma tubes with such assemblies. Our commercial customers, and their customers, have business models based on 10000 hours or more of continuous operation per plasma tube. The Bismuth-based solution produced tubes with 50% less lifetime. Coherent provided test data as part of the previous review process.
4. Indium has limited, and highly constrained applicability based on two factors: It is not a permanent hermetic seal; additionally, deployment would require significant design changes that would jeopardize the installed base. Indium seals on their own cannot accomplish the task without mechanical augmentation that would not be backwardly compatible in the installed base of lasers. A change to plasma tube design now is not practical; our commercial or scientific customers would reject such a change.

In summary, Coherent respectfully requests a continuation of Exemption 32 on the following basis:

- There are no substantive changes to the original submission
    - Almost nothing has changed with respect to the rationale, science, or environmental impact
    - There are no practical alternatives to the use of Pb-based frit as a bonding agent for Argon and Krypton ion laser Brewster window assemblies

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Santa Clara
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- The mass of Pb introduced, both globally, and in the EU on an annual basis is insignificant
- Net Pb due to ion laser windows in the EU is decreasing yearly due to the declining use of ion lasers for all applications
- The risk to all applications and uses globally in terms of loss of established operating performance and longevity outweighs the cost and time to develop a viable alternative to Pb-based frit for this application.

I hope this satisfies your request. Please let me know if you have additional questions.

I would gladly entertain a follow-up phone call, if required.

Sincerely,

Paul T. Ginouves
General Manager
Ion Laser Business Group

+1 408 764 4650

5100 Patrick Henry Drive
Santa Clara
California 95054
Phone (408) 764-4000
Fax (408) 764-4800

www.Coherent.com