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SAFETY PRODUCTS

Health and safety related to laser materials processing.

October - 2003

1 Introduction

This document deals with the special health and safety aspects regarding laser materials processing and especially the radiation hazards, and hazards generated by the laser interaction with materials.

Some of the most important European standards concerning the safety aspects in relation to laser material processing are introduced in this paper.

The safety hazards depend considerably on the type of laser process used. For material processing it is normally either a YAG laser or a CO_2 laser.

2 Laser radiation hazards

The most critical hazard combined to laser processing is the laser radiation being absorbed by the human eye. The laser power and the wavelength are the two factors that have the largest influence on this laser radiation hazard.

Naturally the hazard is increasing with increasing laser power.

The wavelength of the laser beam influence how the laser radiation is absorbed in the eye. Figure 1 shows how the wavelengths between 400 to 1400 nm are focused and absorbed at the retina of the eye.

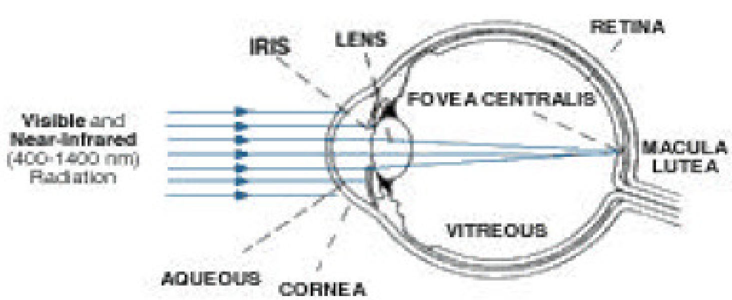

Figure 1 Wavelengths between 400 to 1400 nm enters the pupil of the eye and are brought to focus on the retina, where it is absorbed. (YAG-laser radiation = 1064 nm).

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The most critical wavelengths are the situation shown in figure 2 where the wavelengths are inside or close to the visible range (YAG-laser), which means that the beam will enter the pupil and be focused on the retina. The retina will be heated in a local point, which may result in a loss of vision.

Wavelengths of more than 1400 nm or less than 400 nm is absorbed at the cornea or the lens – see figure 2, which is less hazardous than the situation shown in figure 2.

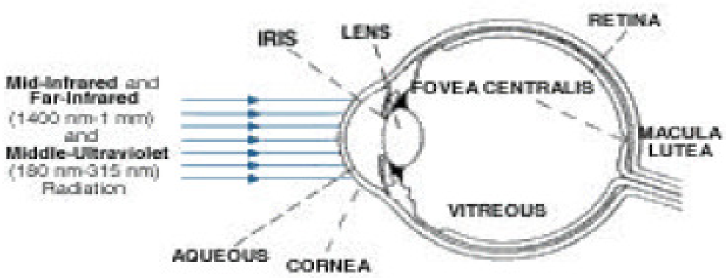

Figure 2 Wavelengths of more than 1400 nm or less than 400 nm are absorbed by the cornea or the lens of the eye. (CO_2 laser radiation = 10600 nm).

This is why the maximum permitted limit of YAG laser radiation for the human eye is about 20 times lower than the maximum permitted limit for CO_2 laser radiation.

Safety aspects of the laser systems for material processing are of major concern and it is of vital importance to be able to shield the operator(s) as well as other personal.

The acceptable level of radiation and maximum permissible exposure time is highly depending on the actual situation when emitting a laser beam.

3 Standards about laser radiation safety

In general humans shall under no circumstances be exposed to laser radiation exceeding the maximum permissible exposure (MPE) limits according to the standards.

Normal practice is to reduce the safety risks for a laser installation to the class 1 for all personnel including the operators of the laser cell.

In the following short introductions to the most relevant European standards about laser safety matters for material processing are given.

Please note that this paper is written in October, 2003, and that new standards currently over time will be published. In addition please note that amendments (with supplements and corrections) exists to some of the standards mentioned.

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Standardization in general.

Standardization at the European regional level is the responsibility of a number of organizations, notable the European Committee for Standardization (CEN) and the European Committee for Electro technical Standardization (CENELEC). CENELEC is responsible for standards related to electrical equipment, CEN for most other items.

Standardization at the International level is also the responsibility of a number of organizations, notably the International Electro technical Commission (IEC, corresponding to CENELEC) and the International Organization for Standardization (ISO, corresponding to CEN).

Unified requirements to industrial products are a cornerstone of the EU. The requirements are specified in directives, which are implemented as national laws in all EU member states. The directives are supported by European codes and standards. The codes and standards are not mandatory. However, relevant codes and standards are mandated which means that the EU declares that conformity to the codes and standards assures conformity to (part of) the corresponding directive(s). This presents, of course, a practical hindrance for the application of non-European codes and standards, including international standards because the effort involved in documentation of the compliance of such non-European provisions to the relevant directive(s) easily may be prohibitive.

However, CEN and ISO have signed an agreement (the Vienna Agreement) which means that standards may be prepared and published as combined EN ISO standards (having the same number).

It has to be stressed that the European "system" results in a hierarchy of standards and codes:

1. Laser equipment is covered by a number of directives and the related mandated EN standards for laser safety apply. This also includes ISO standards, prepared under the Vienna Agreement.
2. Where provisions are missing at the European level, national European standards may be used (because they are supposed to be compatible with national laws which again implements the directives.
3. ISO standards, not prepared under the Vienna Agreement (guidance only).
4. Non-European national standards (guidance only)

(2) was the common choice some years ago when only a few EN standards existed but most national standards are rapidly being substituted by EN standards in the EU (and associated countries).

On the website of CEN (**http://www.cenorm.be**), it is possible to search for relevant standards on the subject.

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prEN ISO 11553-1

The European standard **prEN ISO 11553-1**:"*Safety of machinery – Laser processing machines" Part 1: "General safety requirements*", 2002, covers radiation hazards and hazards generated by the laser interaction with materials and substances. It also specifies the information to be supplied by manufacturers of such equipment.

This standard requires that the manufacture of a laser material processing machine shall perform a risk assessment in every individual laser installation. It further requires that the manufacture shall comply with the safety requirements and measures stipulated in the standard and in addition be responsible for the compliance of the whole machine including subassemblies.

EN 60825-1 (with Amendment 1 and 2)

The most important and comprehensive European standard on the topic is the **EN 60825-1**: "*Safety of Laser Products – Part 1: Equipment classification, requirements and user's guide*". This standard deals with the safety of laser products. The standard covers laser radiation in the wavelength range 180 mm to 1 mm, and indicates safe working levels of laser radiation and introduces a system of classification of lasers and laser products according to their degree of hazard.

The EN 60825-1 standard specifies Maximum Permissible Exposure (MPE) values, which represents the maximum level of laser radiation to which the eye or skin can be exposed without injury.

MPE limit values are for users, set below known hazard levels, and are based on the best available information from experimental studies. The MPE values should be used as guides in the control of exposure, and should not be regarded as precisely defined dividing lines between safe and dangerous levels.

In any case, exposure to laser radiation shall be as low as possible. The MPE are divided into two levels one for skin exposure and one for ocular exposure the latter being significantly lower than the first.

The MPE value depends on the wavelength, on the exposure time and on the beam divergence – see table 6 in EN 60825-1/A2, 2001.

Furthermore the EN 60825-1 standard contains guidelines to calculate the nominal ocular hazard distance (NOHD), which represents the safe distance to a laser source.

This is illustrated in figure 3.

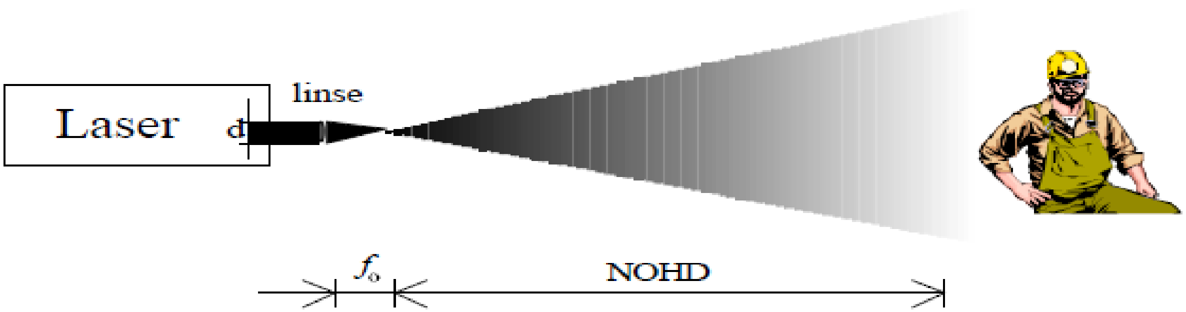

Figure 3 Nominal Ocular Hazard Distance (NOHD)

The hazard potential for class 3B and 4 lasers may extend over a considerable distance. The range from the laser at which the irradiance or radiant exposure falls below the appropriate MPE is termed the nominal ocular hazard distance (NOHD). The area within which the beam irradiance or radiant exposure exceeds the appropriate MPE is called the nominal ocular hazard area (NOHA). This area is bounded by the limits of traverse, elevation and pointing accuracy of the laser system and extends either to the limit of the NOHD or to the position of any target or backstop. The exact NOHA will also depend on the nature of any material within the beam path, e.g. specula reflectors.

The NOHD depends on the output characteristics of the laser, the appropriate MPE, the type of optical system used, and the effect of the atmosphere on beam propagation.

The NOHD can be calculated after the equations in EN 60825-1.

EN 60825-4 (with Amendment 1 and 2)

The standard EN 60825-4: "Safety of laser products - Part 4: Laser guards", specifies the requirements for laser guards, permanent and temporary (for example for service), that enclose the process zone of a laser processing machine and specifications for proprietary laser guards.

This standard applies to all parts of a guard including screens, panels and other part of a protective housing.

Material intended to be used as screening material against laser radiation has to fulfil the requirements stated in this part 4 of EN 60825.

When the front surface of a laser guard is subjected to laser radiation at the foreseeable exposure limit (FEL), the laser guard shall prevent laser radiation accessible at its rear surface from exceeding class 1 at any time over the period of the maintenance inspection interval.

EN 60825-5

Safety of lasers products, Part 5: Manufacturer´s checklist for EN 60825-1, Part 1: Equipment classification, requirements and user´s guide

This checklist is intended for use of manufactures of laser products to establish that the equipment complies with the requirements in EN 60825-1.

EN 60825-10

Safety of laser products - Application guidelines and explanatory notes to EN 60825-1

This Technical Report gives information on the physics relating to the dangers posed by laser products. It complements, but does not replace, the information in EN 60825-1 by explaining the underlying principles. The application of this technical report is limited to laser products with finite accessible emissions of laser radiation.

EN 207 (with Amendment 1)

In the case of potential risk of exposure of the eye, the use of safety goggles are a convenient solution. The labelling and use of safety goggles are regulated by the European standard EN 207 in the case of goggles for operators.

The use of filters as viewing screen is also regulated by the European standard EN 207.

EN 208 (with Amendment 1)

Safety goggles for service is regulated by the European standard EN 208.

4 Secondary radiation

Concerning secondary radiation two phenomenon's are possible to arise. Photo Ceratitis, often described as "welders flash" has a quite frequent occurrence among arc welders, and is painful but normally without permanent damage. Blinding is the second risk, which is rare but might cause permanent damage to the eye.

In both situations the risks and the safety aspects are well known and intensively described in the literature. End users who deal with arc welding are normally familiar with these safety aspects.

In the case of pure YAG laser welding the secondary radiation is without significance.

In the case of the hybrid process (laser combined with MAG) it is the MAG process parameters that dictates the level of secondary radiation. The levels of UV- and visible radiation can be very intense in high power MAG welding of steel.

However the laser process is automated and that removes the operator from the processing area, thus less hazardous. If required personal safety equipment like helmets, clothes and protection glasses are standard.

5 Emission of fume and gas

The emission of fume and gas are a lot more difficult to predict, as this depends a lot on the actual process situation. The deposition rates of filler material and the process synergy have a particular impact on the fume and gas emission.

Similar as for secondary radiation the laser process is automated which removes the operator from the processing area, thus less hazardous.

6 Other hazards

Of other potential hazards than the laser radiation hazards from the laser processing machines can be mentioned:

- Mechanical hazards (Moving parts as gantries and robots)
- Electrical hazards (High voltages)
- Noise hazards
- Thermal hazards
- Vibration hazards
- Fire or explosion

These kind of hazards from laser processing are not covered in prEN ISO 11553-1 or EN 60825 and instead the laser machinery should comply as appropriate especially with the standard: **ISO/TR 12100** "Safety of Machinery", 1992, and in addition with other relevant standards on the respective fields.

Concerning the fire risk this is present if laser radiation accidental hits flammable material and to prevent this, flammable material should not be present around the working area.

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