Human limitations as safety factor considerations in Femtosecond Laser beam alignments

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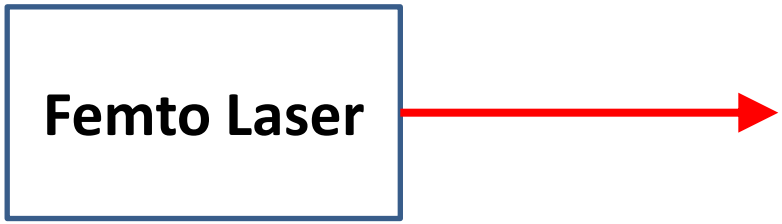


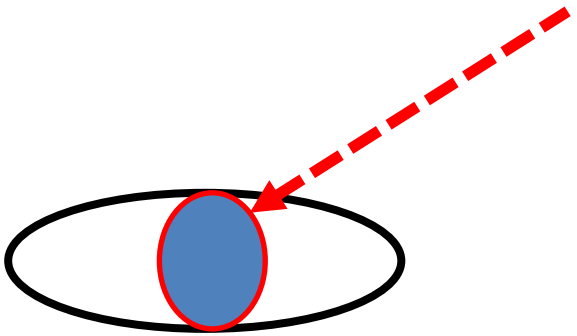
Femtosecond Ti:Sapphire Laser - basic parameters

- **Ti**:**sapphire** laser is usually **pumped** with another laser with a wavelength of 514 to 532 **nm** and operate at **800 nm** central **wavelength** and have about **20 nm FWHM or more**
- **High peak power.** Because of its extremely short pulse duration the peak power could be extremely high

$$P_{peak\to\infty} = \frac{E}{\Delta t \to 0}$$

Femtosecond Ti:Sapphire Laser Accidents

- Typical 800 nm wavelength **is visible** at high powers
- Tens **known accidents**
- Many accidents ended with irreversible foveal damage. Sometimes in both eyes.



Common causes for eye injuries occurring during beam alignment

- Frequent **incorrect eyewear selection** and/or eyewear failure is one of the primary common causes for eye accidents
- Conflict between **safety** and **performance** criteria cause failure to use available eye protection due to inability to view adequately the beam path and location
- Eye exposure due to **unanticipated reflection** during laser alignment

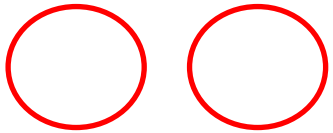
Eye hazards from ultrashort lasers are different than those caused by other lasers

- Ultrashort laser high pulse power density may cause saturation of the eyewear absorption ability, and thus reduce the optical density of the eyewear

- Ultrashort laser pulses have a large bandwidth and a broadband filter is required

- Threshold energy for eye injures is much lower than in longer pulsed lasers

- Injury can also result from exposure to a diffuse or stray light reflection



- Diffuse reflection can cause **bilateral** foveal damage

- Focused ultrashort laser by the optical **kerr lens effect**

$$N = N_0 + N_2 I$$

$$N_0 >> N_2$$

High Irradianc

Root causes of accidents

- Each IR card has a typical IR absorption and visible emission band

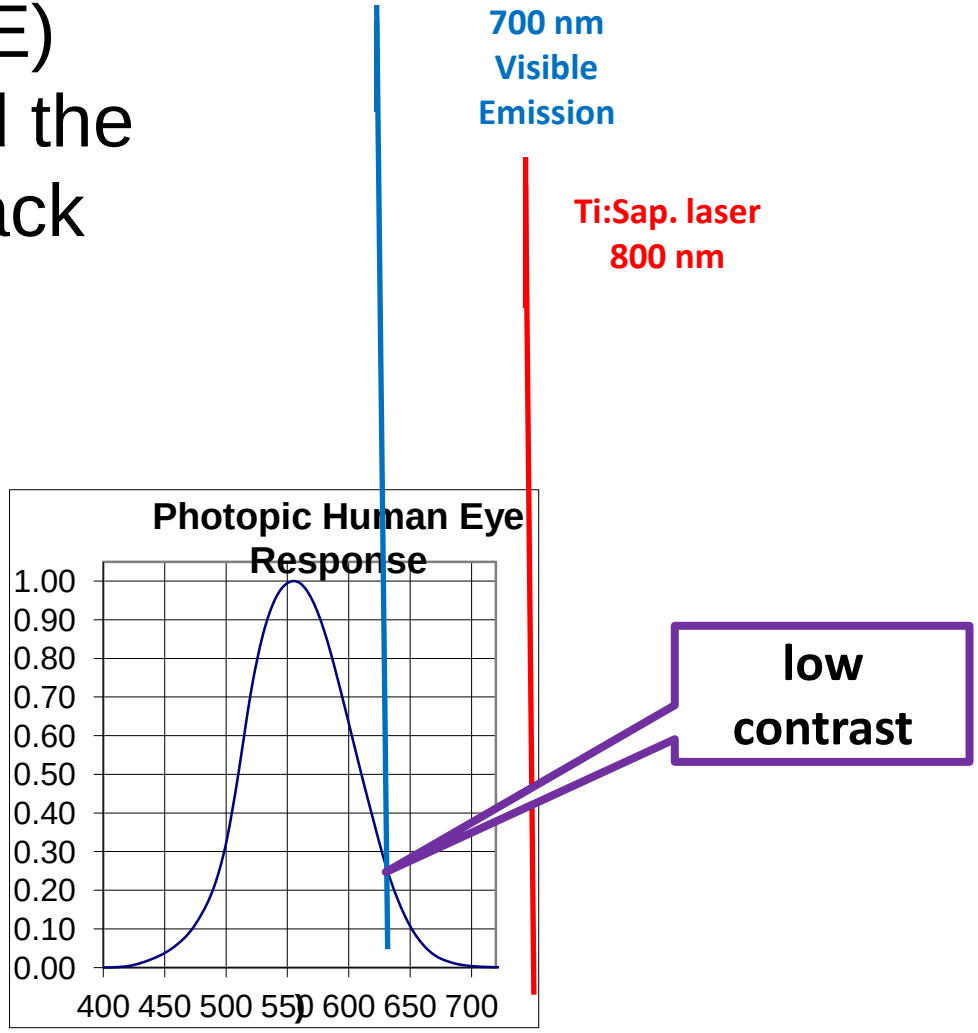
- Each laser safety eyewear has a typical transmission depending on the wavelength

NIR

Absorption

Visible light

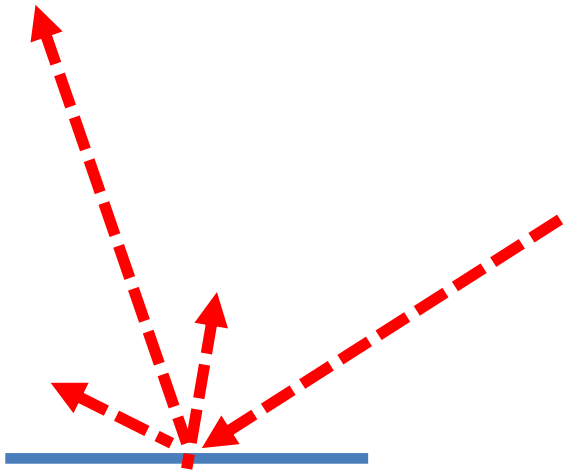
Incorrect selection of laser protection eyewear (LPE) spectral attenuation and the infrared viewer create lack of contrast and low VLT



- Some IR cards are saturated and cause a “blooming” effect

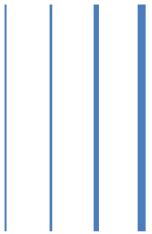
- Most IR cards have diffuse reflections

- Plastic coating of some IR cards have partial specular component reflection



Root causes of laser safety eyewear removal

- When the IR card is saturated causing a “blooming” effect and **a large fuzzy spot** disturbs the beam alignment procedure
- Low Visible Light Transmission (VLT) affects the **contrast sensitivity** and prevents from viewing the beam location precisely enough to get centered on the optics element
- **Underestimation of the risks** involved **due to poor training**



Lower light → Lower resolution

Before ultrashort laser alignment starts, the lab PI/laser supervisor must check the following:

- The researcher received **a proper** laser safety training

- The laser safety eyewear is comfortable for the user and has the required **ultrashort lasers level of protection** with a proper attenuation

- The laser safety eyewear **VLT,** the **Invisible laser alignment detector** and **lighting conditions together** should enable to see all the optical elements accurately enough for the beam alignments

Thank You

Questions?