Reflective (Interference) Laser Protective Eyewear: Construction, Properties, Application

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Protective Equipment is the last line of defense in your laser safety arsenal.

Laser Safety Hazard Analysis

- Laser Classification
- Identify Nominal Hazard Zones
- Determine Personnel Access

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Engineering Controls

- Protective Housings
- Enclosed Beam Paths
- Interlocks
- Beam Stops

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Administrative Procedural Controls

- LSO & Management Oversight
- Policies & Procedures of Operation

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Protective Equipment

- Eyewear
- Screens / Barriers / Curtains
- Windows

Coated Laser Eye Protection is one of several LEP technologies.

Types of Laser Eye Protection

Absorptive

Dyes and minerals embedded in glass and polymer substrates

Reflective

Dielectric coatings to create reflective interference for particular wavelength(s)

Hybrid

A combination of absorptive and reflective technologies

Characteristics of Coated LEP

Bandwidths

Can be designed to block narrow bandwidth ranges (i.e., notch filter)

Visible Transmission

Have generally higher VLT given wavelength specific designs

Color Recognition

Improved VLT generally equates to improved color recognition

Angle of Incidence

Potential for passage of laser energy at oblique angles. Filter is designed to be safe for viewing at all angles.

Production of dielectrically coated laser eye protection (LEP):

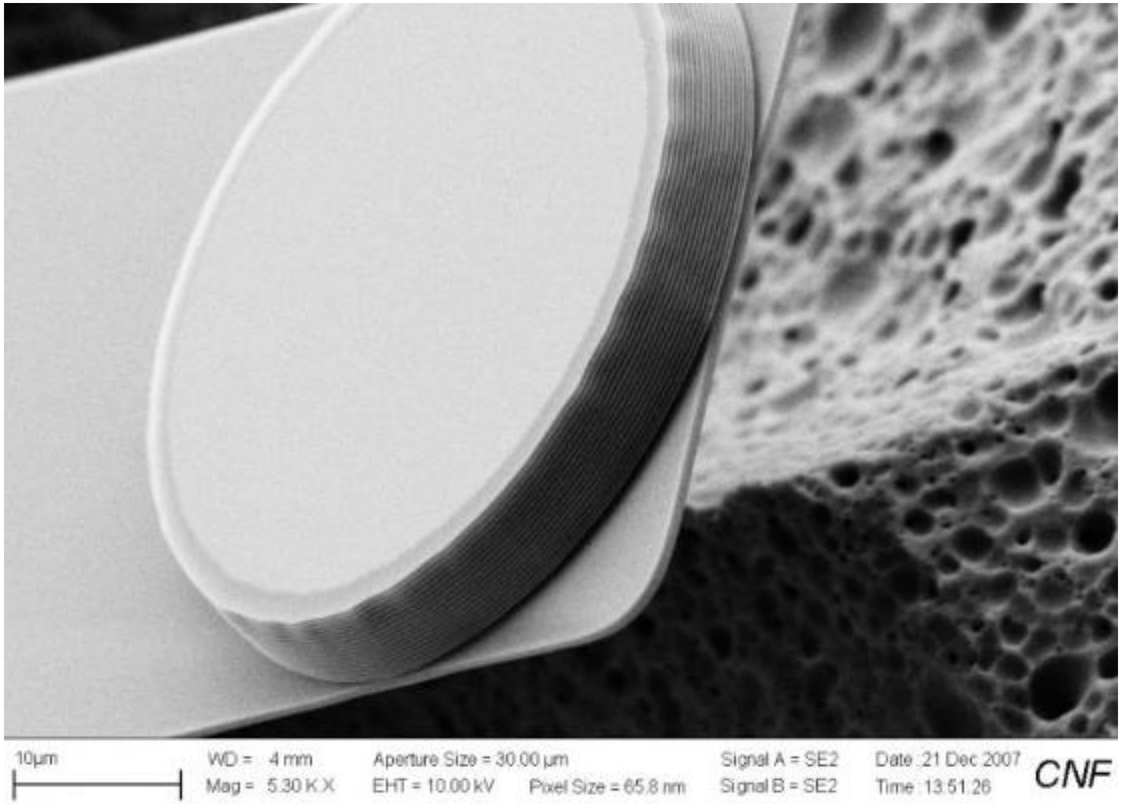
- Dielectrically coated interference filters may be produced in three sections
  - One of which determines the central wavelength (λ) of blocking interest, its half band width (λ/2) and the shape of the transmittance curve
  - The other two control the degree and range of blocking outside of the central wavelength

- The central wavelength section of an interference filter is created by repetitive deposition of thin layers of partially reflecting dielectric compounds
  - Multiple layers are precisely and evenly deposited
- Generally, the thickness of each layer is equal to a quarter wave (λ/4) of the filter's central wavelength
  - Alternating layers of dielectric materials with higher and lower refractive indices make up a stack
- Generally, a half wave layer(s) is then deposited between symmetric stacks to form a spacer layer
  - The half bandwidth of the interference filters is determined by the ratio of the indices of the higher and lower dielectric materials
  - The number of layers in a stack
  - And the number of half waves in a spacer
- The spacer layer and its adjacent stacks form a "cavity" which constitutes the basic element of an interference reflective filter
  - The number of cavities in the band pass section then determine the overall shape of the transmittance curve

NOTE: rejection of wavelengths resulting from reflective interference is limited to ~15% of the central wavelength. Consequently, the reflectance value diminishes with deviation from the central wavelength.

  - Example: an LEP dielectric filter providing – and inscribed with – an OD of 6 @ 532nm may only possess an OD of ≤3 at 527nm.

Here’s a stack of 1 micron film layers viewed under microscope.



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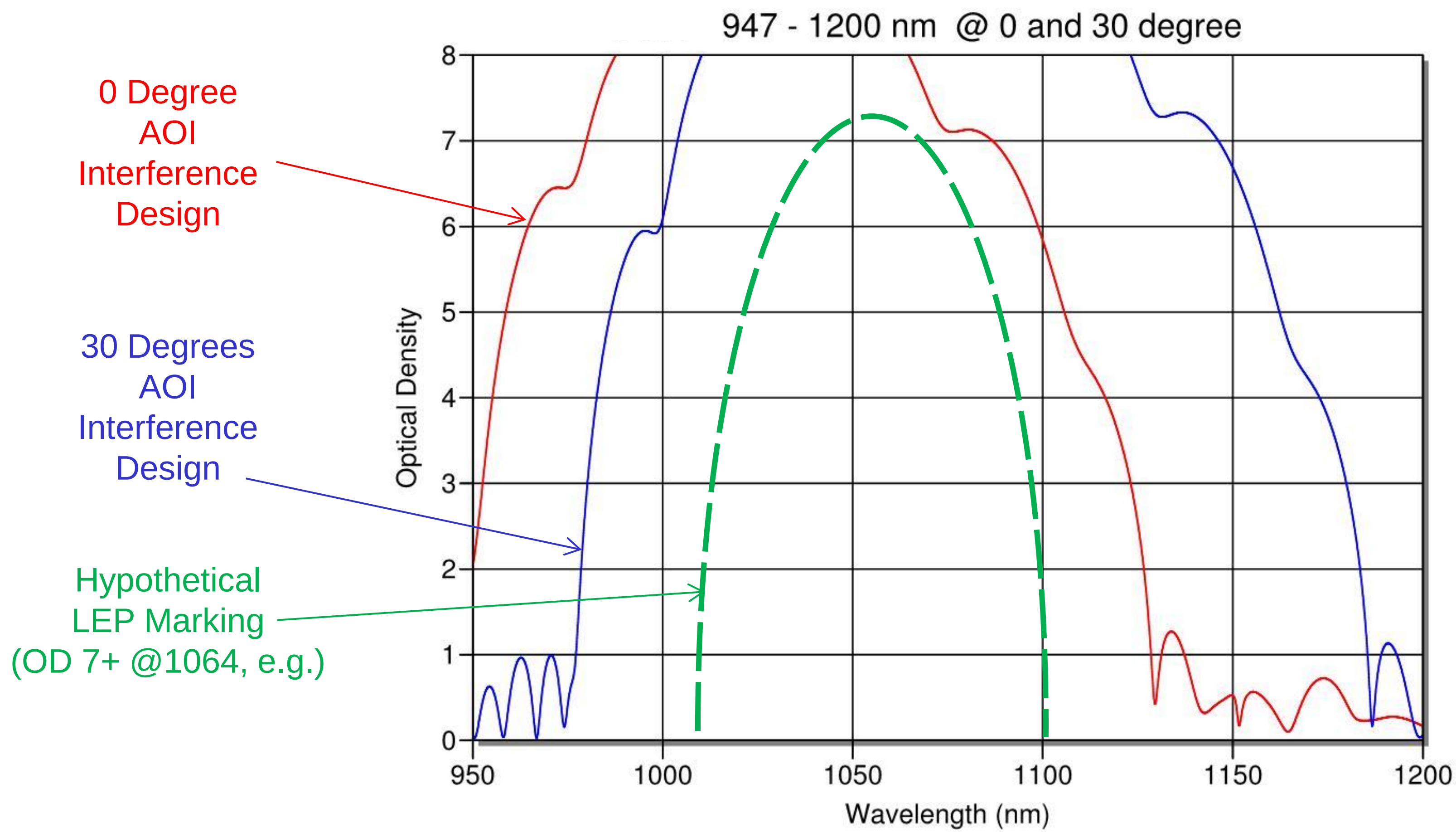
ANSI Z136.7 and CE/EN207 specify protection within the angle of incidence (AOI) band from 0 degrees to 30 degrees. Eyewear markings should reflect this.



What are possible “tradeoffs” to using reflective LEP?

Pros:

- Increased VLT by blocking narrowly defined region of visible wavelengths
- Highest level of damage threshold capability; well-suited for high irradiance conditions
- Multiple lasers, multiple wavelengths; application of coatings to mineral glass, for example, may significantly increase the wavelength region of attenuation

Cons:

- Dielectrically coated LEP are themselves reflecting incident laser beam(s)
- Back scatter from ambient incident light may prove distracting
- Surface scratches may impact protection levels

Using analogies from a time-honored game of strategy, we remind you that Protective Equipment is the last line of defense in your laser safety arsenal.

From the Boris Spassky* School of Laser Safety:

Engineering Controls

- King and Castles: Limited movement by both pieces
  - Difficult to move
  - High costs in any movement
- Protection of the King ensures a Class 1 environment

Administrative and Procedural Controls

- Queen (rules established by the LSO and/or management)
- Bishops (policies)
- Knights (procedures)

Protective Equipment Controls

- Pawns (eyewear, barriers, curtains, windows)

* The tenth World Chess Champion, holding the title from 1969 to 1972