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Improved ITO laser resistance by imbedding within a Fabry Perot filter

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Improved ITO laser resistance by imbedding within a Fabry-Perot filter

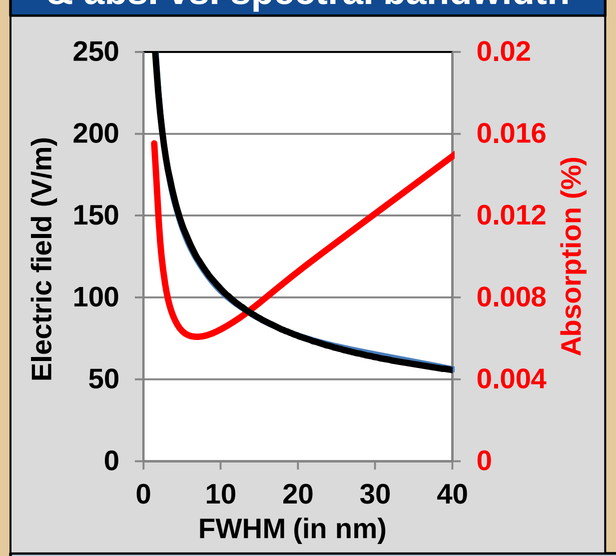
Christopher J. Stolz (LLNL, USA) & Anna Sytchkova (ENEA, Italy)

Introduction

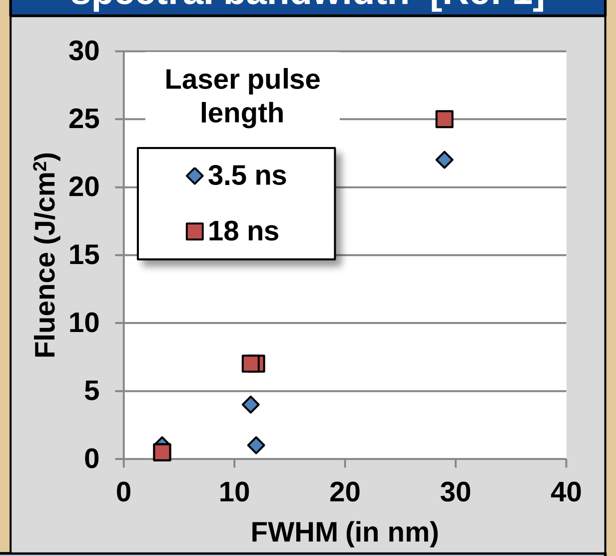
ITO has a low LIDT due to laser absorption of the free carriers

- A multilayer Fabry-Perot (F-P) filter both simultaneously has high transmission with low electric field positions within the coating
- Embedding ITO into an electric field minimum reduces the effective absorption by over an order of magnitude
- The proper F-P filter spectral bandwidth is a compromise between reduced effective absorption and higher resonant electric fields

F-P filter (with ITO) electric field & abs. vs. spectral bandwidth



F-P filter (non ITO) LIDT vs. spectral bandwidth [Ref 1]



- Fabry-Perot filter was designed at oblique incidence (41°) to enable angle tuning for this proof of concept
- Spectral bandwidth was 14 nm ("S" pol.) and 36 nm ("P" pol.)

1. C. J. Stolz, M. Caputo, A. J. Griffin, and M. D. Thomas, "1064-nm Fabry-Perot Transmission Filter Laser Damage Competition" in Laser-Induced Damage in Optical Materials: 2014, G. J. Exarhos, V. E. Gruzdev, J. A. Menapace, D. Ristau, and M. J. Soileau, eds., Proc. SPIE 9237 92370N-1-6 (2014).

Fabry-Perot filter fabrication

- Magnetron r.f. sputtering in an Ar atmosphere
- H = Hafnia (99.9% pure target excl. Zn) at 400 W (1% inlet of O_2)
- L = Silica (99.995% pure target) at 400 W (No O_2)
- M = ITO (In_2O_3:SnO 10 st%, 99.99% pure) at 220 W (No O_2) [Ref. 2]

- Sample 1: Fabry-Perot filter

  20 layers with 10 nm of imbedded ITO

  Substrate/ ((HL)^4 0.963H (0.072M) 1.972L H(LH)^4) /Air

  Transmission 96.2% "P" 98.7% "S"
- Sample 2: 10 nm thick single ITO layer

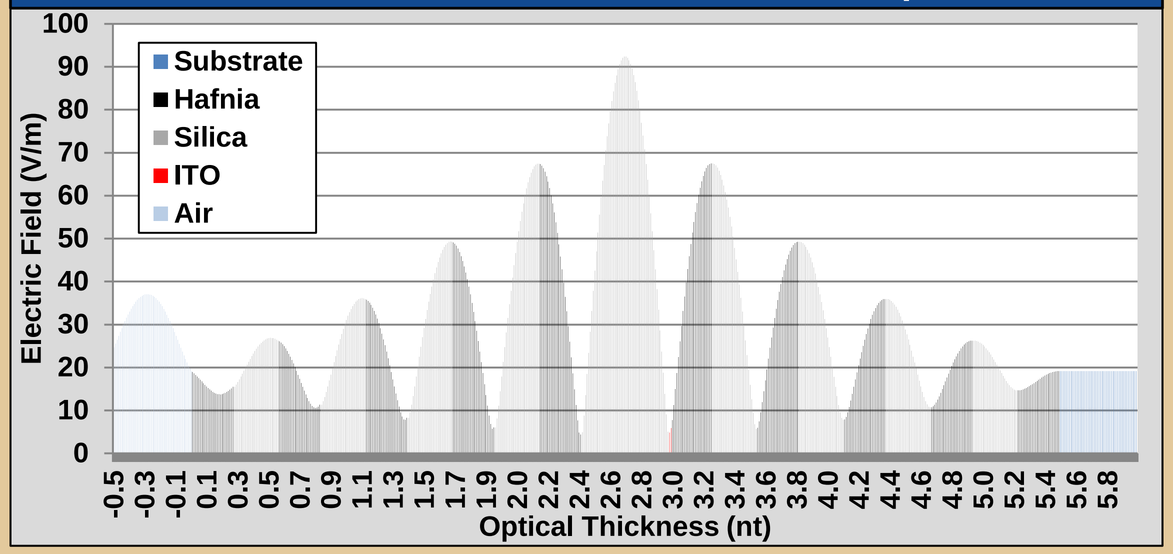
  Film resistivity: 1.7×10^{-4} Ω cm

2. A. K. Sytchkova, M.L. Grilli, S. Boycheva and A. Piegari, "Optical, electrical, structural and microstructural characteristics of r.f. sputtered ITO films developed for art protection coatings", Applied Physics A – Matter, A 89 (2007), 63-72.

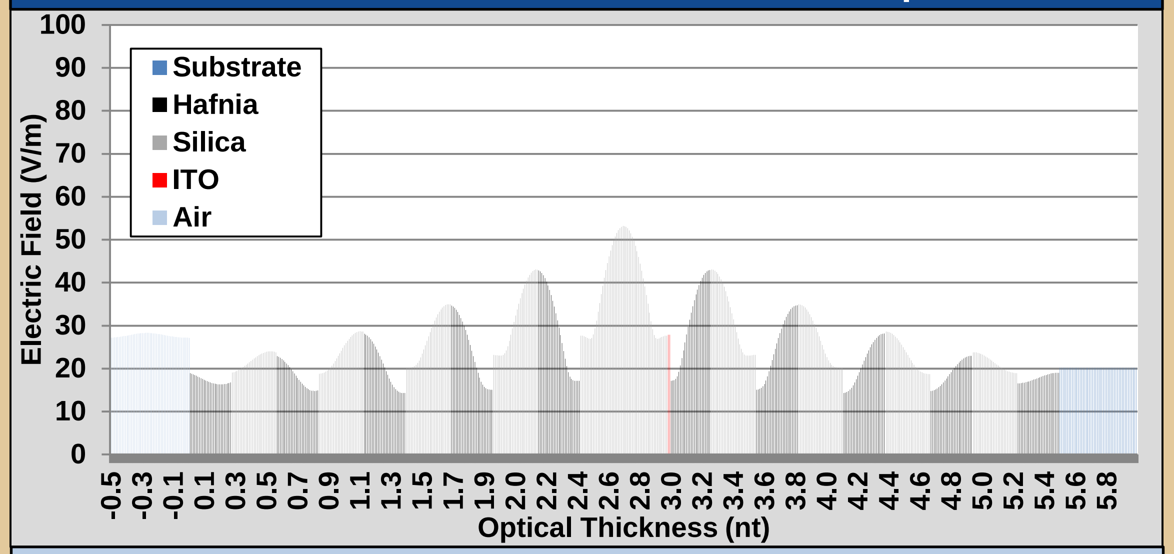
Model

Standing wave electric field profiles

F-P filter with embedded ITO at 41° "S" pol.



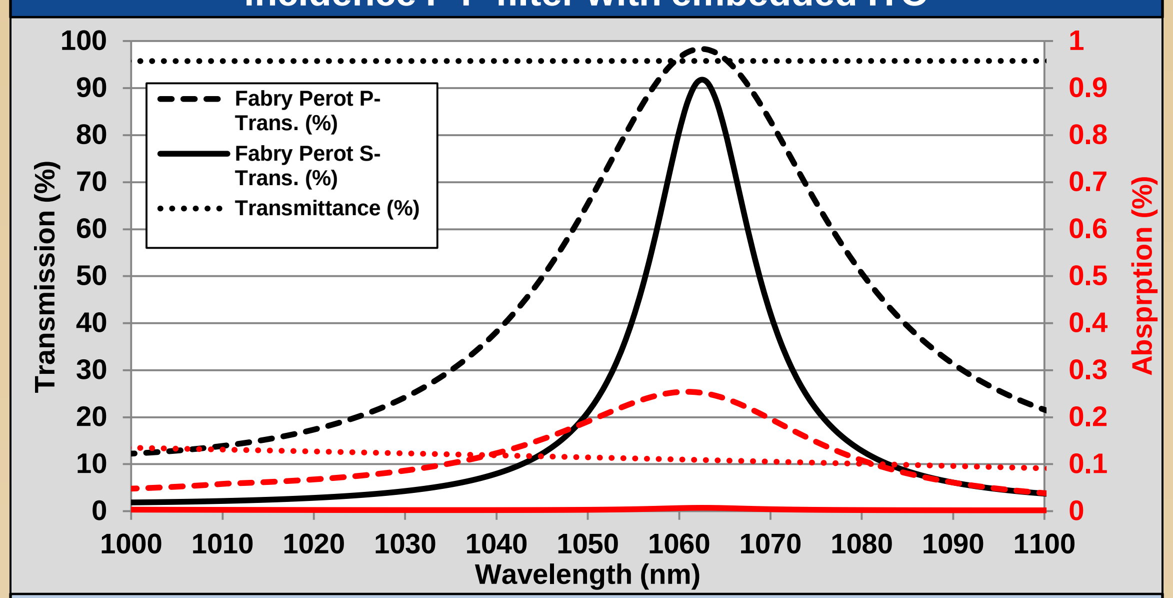
F-P filter with embedded ITO at 41° "P" pol.



Electric field impact can be studied by testing at both polarizations

Theoretical transmission and absorption

Single normal incidence ITO layer versus a 41 degree incidence F-P filter with embedded ITO

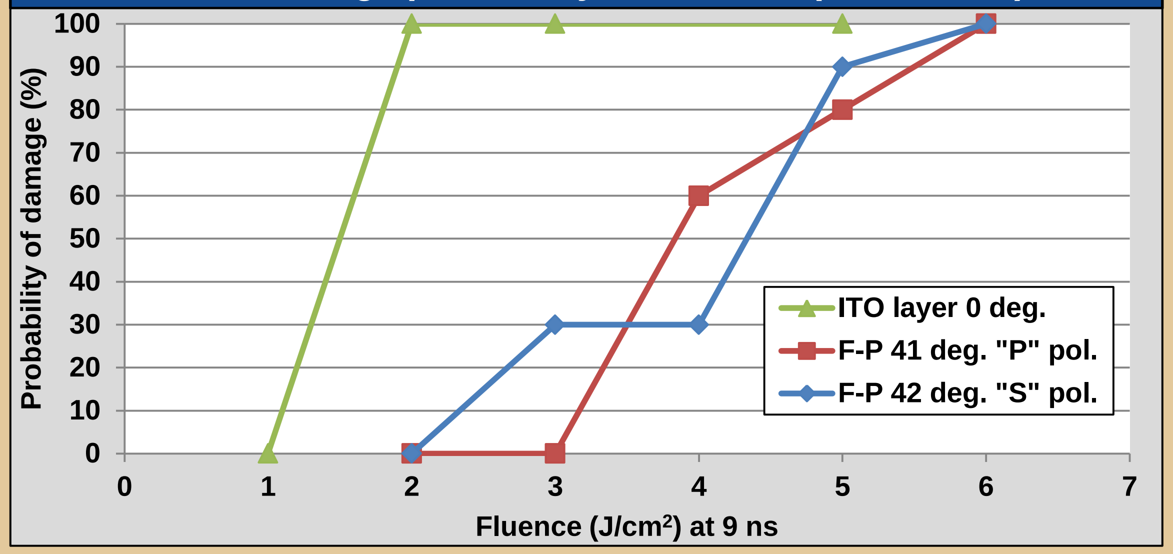


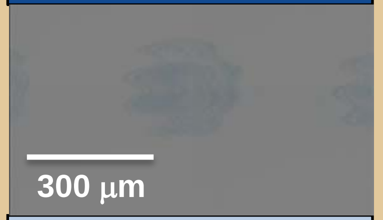
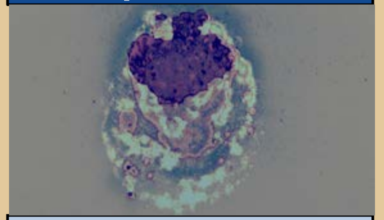
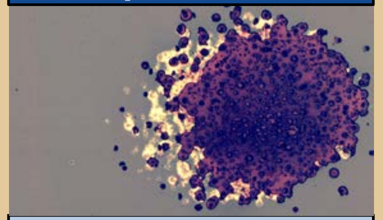
Exploitation of polarization-induced differences reveals the impact of absorption on the laser-induced damage threshold

Results

Laser damage testing reveals the Fabry-Perot approach increases the survivability fluence of ITO

Laser damage probability at 1064 nm (1000 shots)



ITO layer (0°)	F-P filter (41°) "P" polarization	F-P filter (42°) "S" polarization
		
2 J/cm² (1000 shots)	5 J/cm² (1000 shots)	5 J/cm² (1000 shots)

- 650 µm ± 30 µm 1/e² diameter beam diameter
- 10 sites per fluence spaced 2 mm apart
- 1,000 shots at 10 Hz
- Visual damage detection with optical microscopy

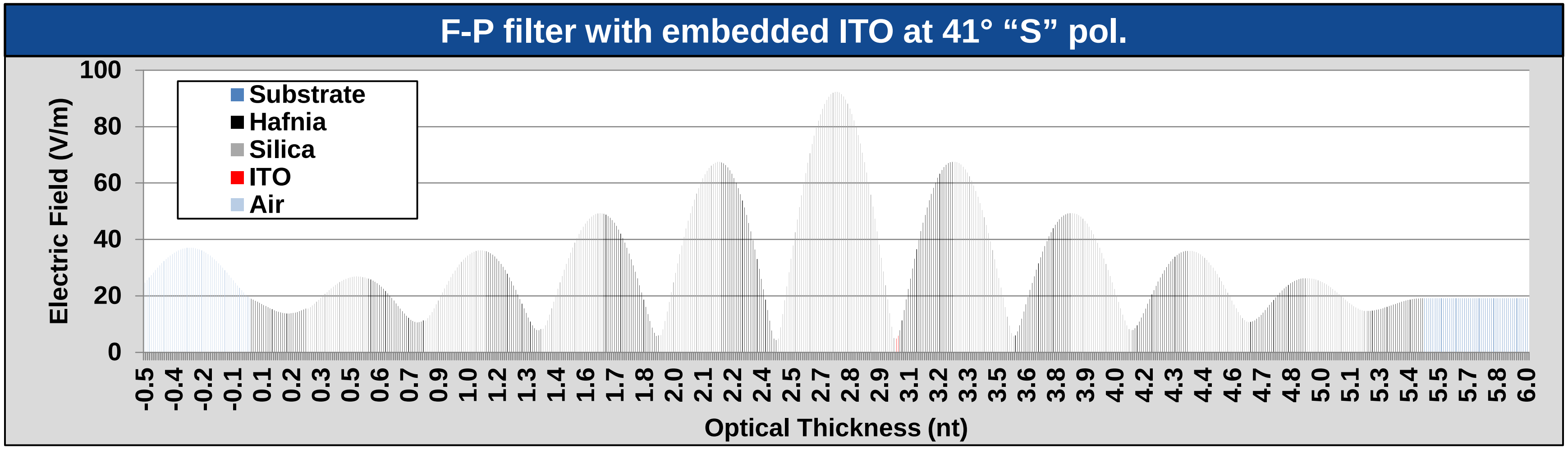
Conclusions

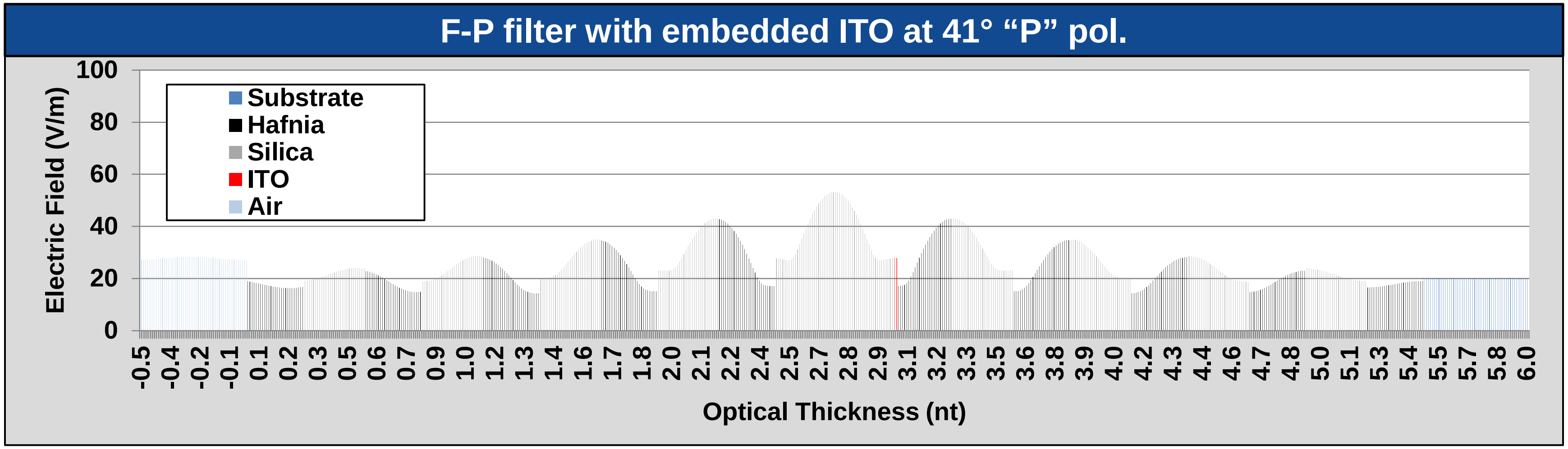
- Imbedding an ITO layer within a Fabry-Perot filter significantly reduces the electric field within the ITO layer
- The Fabry Perot filter design is a compromise between reduced effective absorption and higher resonant electric fields
- Laser resistance is improved by imbedding an ITO layer
- Part of the improvement is due to incident angle differences (scales as the projected angle)
- Coating non-uniformity and defects should be studied in more depth to better understand laser damage results

Acknowledgements

The authors would like to recognize Marlon Menor and John Adams from LLNL for their assistance with laser damage testing

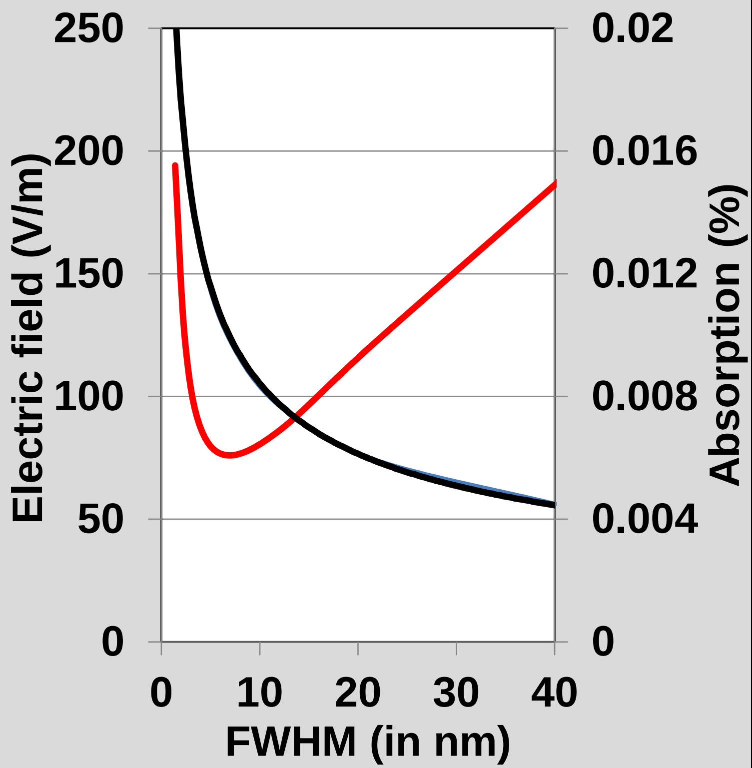
A Fabry Perot filter design has simultaneous high transmission and low electric field regions



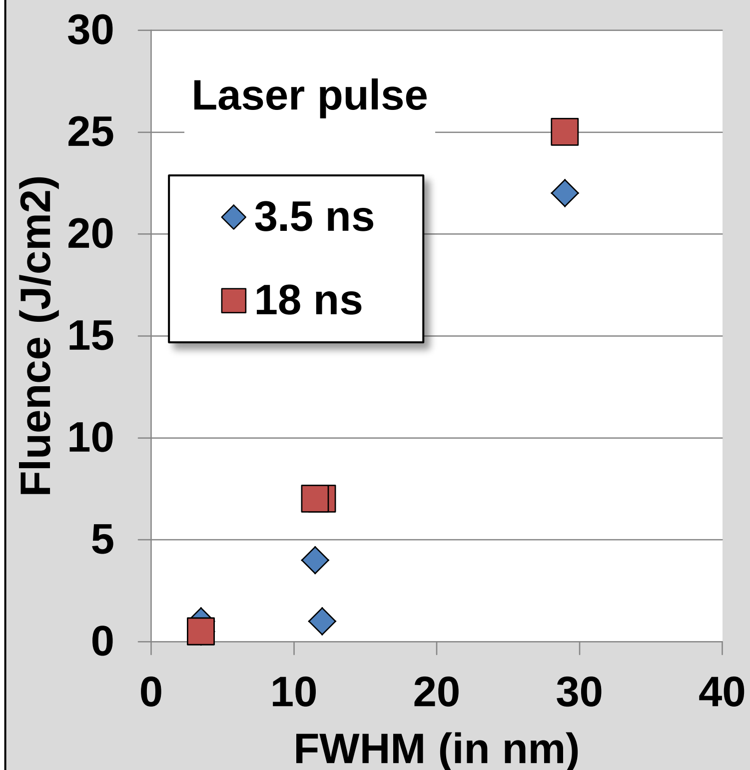


The Fabry Perot filter is a compromise between low effective absoprtion and high resonant electric fields

F-P filter (with ITO) electric field & abs. vs. spectral bandwidth



F-P filter (non ITO) LIDT vs. spectral bandwidth [Ref 1]



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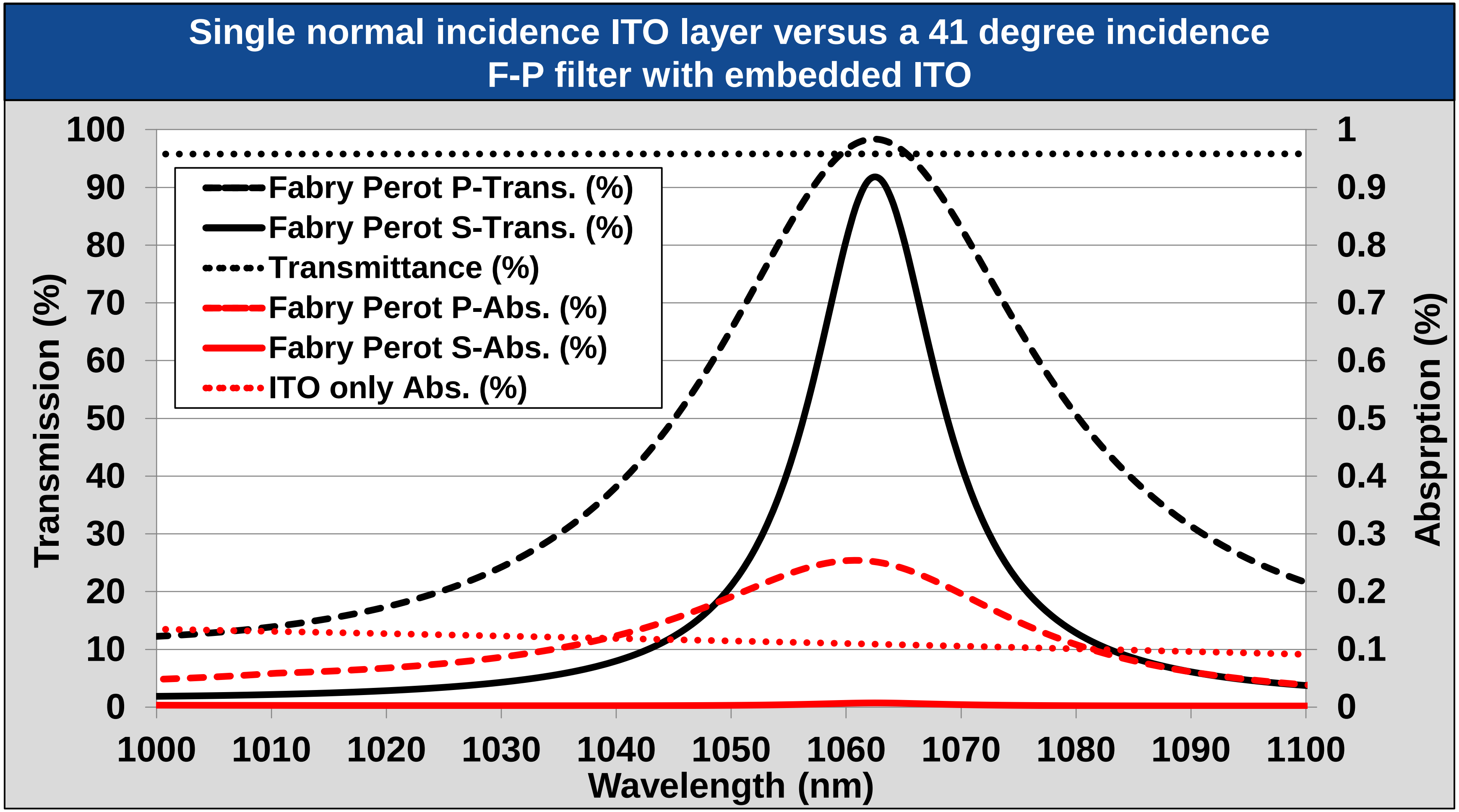
Imbedded ITO layer at "S" polarization has an effective reduced absorption greater than 10×



The coatings were manufactured with magnetron r. f. sputtering

- **Magnetron r.f. sputtering in an Ar^+ atmosphere**
- **H = Hafnia (99.9% pure target excl. Zn) at 400 W (1% inlet of O_2)**
- **L = Silica (99.995% pure target) at 400 W (No O_2)**
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- **Sample 1: Fabry-Perot filter**

  20 layers with 10 nm of imbedded ITO

  Substrate/ ((HL)^4 0.963H (0.072M) 1.972L H(LH)^4) /Air

  94.8% transmission
- **Sample 2: 10 nm thick single ITO layer**

  3.5 kOhm (2 pt. Probe)

2. A. K. Sytchkova, M.L. Grilli, S. Boycheva and A. Piegari, "Optical, electrical, structural and microstructural characteristics of r.f. sputtered ITO films developed for art protection coatings", Applied Physics A – Matter, A 89 (2007), 63-72.

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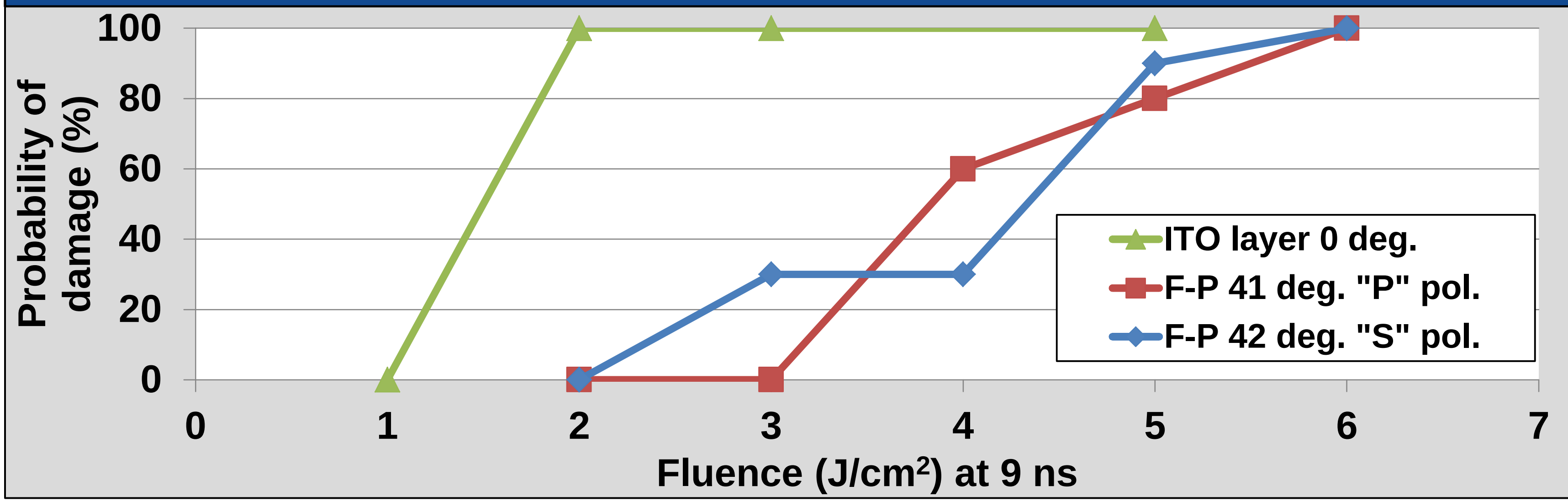
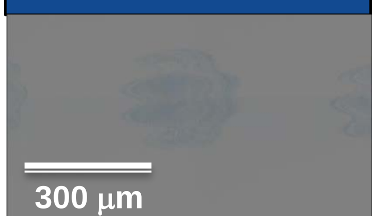
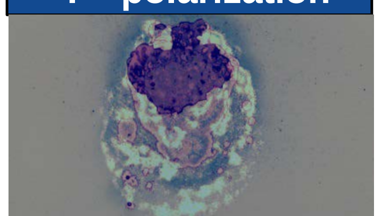


ITO layer (0°)



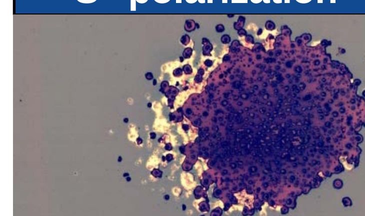
2 J/cm^2 (1000 shots)

F-P filter (41°)
"P" polarization



5 J/cm^2 (1000 shots)

F-P filter (41°)
"S" polarization



x J/cm^2 (1000 shots)