Damage resilience testing of broadband thin-film coatings for use in a high-energy Ti:Sa amplifier system

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Extreme Photonics Applications Centre (EPAC)

EPAC is a new research facility currently under development at the STFC Central Laser Facility (CLF) in the UK (Fig. 1). It will house a titanium-doped sapphire (Ti:Sa) laser amplifier that will operate at a 10 Hz repetition rate to deliver compressed pulses of PW peak power for applications of laser-driven radiation and particle sources [1].

To achieve this high power it is key that optics are resilient to laser induced damage (LID). We are performing independent in-house damage resilience tests to ensure that our standards are met.

Figure 1: *The Extreme Photonics Applications Centre building. Credit: STFC*

Coating Samples

We report results for broadband highly reflective coatings for the EPAC Ti:Sa amplifier, comparing samples from different suppliers and deposition techniques, which include:

- Electron beam evaporation (EBE)
- Magnetron beam sputtering (MBS)
- Ion assisted deposition (IAD)
- Ion beam sputtering (IBS)

All coatings are quoted to be over 99.5% reflective for s-polarised light at 45° angle of incidence.

Testing Conditions

The uncompressed beam from CLF's Astra-Gemini facility was used for damage resilience testing. Table 1 lists the EPAC Ti:Sa beam specifications and the testing conditions. Due to the difference in pulse duration, the $\sim\tau^{0.5}$ scaling law is used to estimate the damage fluence for EPAC.

Parameter	EPAC Specification	Testing Condition
Pulse duration (FWHM)	3 ns	0.5 ns
Centre wavelength	800 nm	810 nm
Linewidth (FWHM)	100 nm	35 nm
Fluence	1.8 J/cm^2	up to 1.2 J/cm2*
Environment	Ambient air	Ambient air

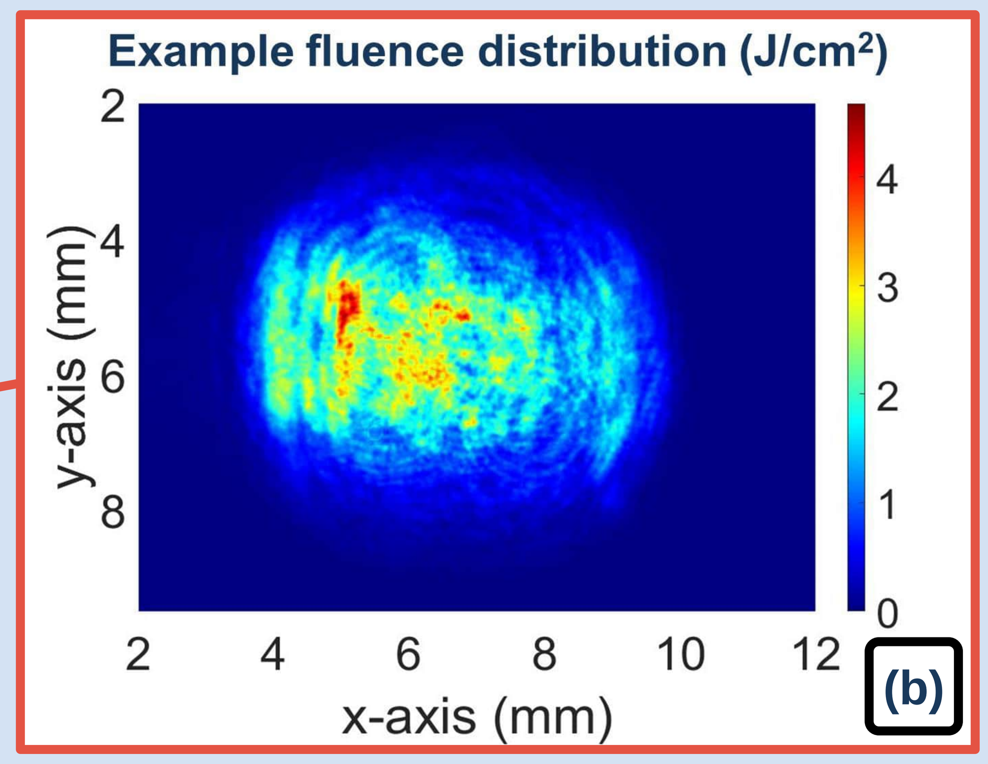
***equivalent to 2.9 J/cm2 for 3 ns pulses**

Table 1: *A summary of the key requirements and testing conditions for the mirror coatings in EPAC's main amplifier.*

The Setup

The layout in Fig. 2 shows the key parts of the test setup and the inserts show example data that was gathered during the experiments.

The fluence distribution in insert **(b)** shows hotspots on the beam profile, but the damage did not usually occur in those areas, therefore the average fluence distribution is used as the indicator of the performance of the optics.



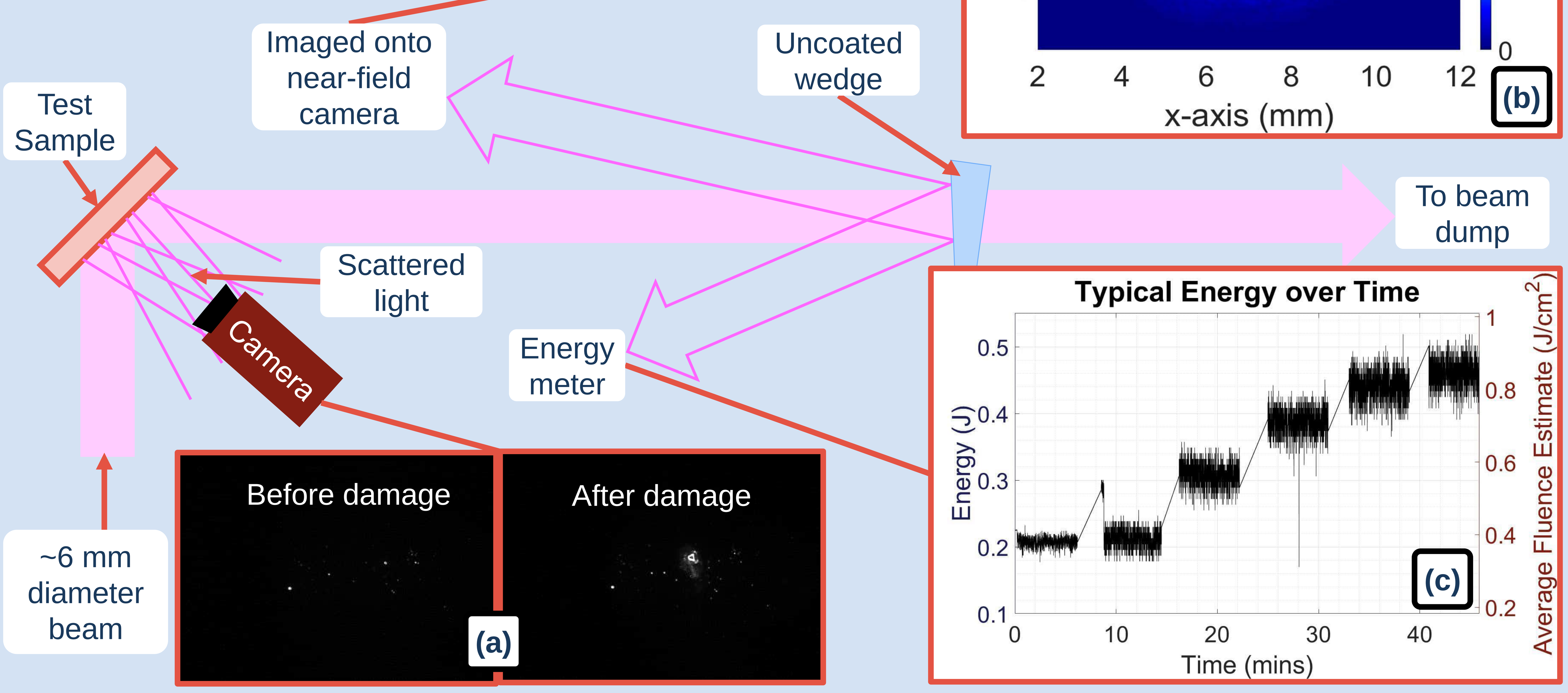


Figure 2: *A diagram showing the key components of the test setup.*

A CCD camera imaging light directly scattered from the test sample is used to detect initiation of damage. Insert ***(a)*** *shows a typical view before and after damage has occurred.*

Insert ***(b)*** *shows an example of the beam profile that is relay imaged from the test sample onto another CCD camera. It also shows the fluence distribution for the maximum incident energy for that sample.*

Insert ***(c)*** *shows a typical graph of pulse energy over time, as well as an estimate of the average fluence – calculated by dividing the pulse energy by an estimate of the beam area.*

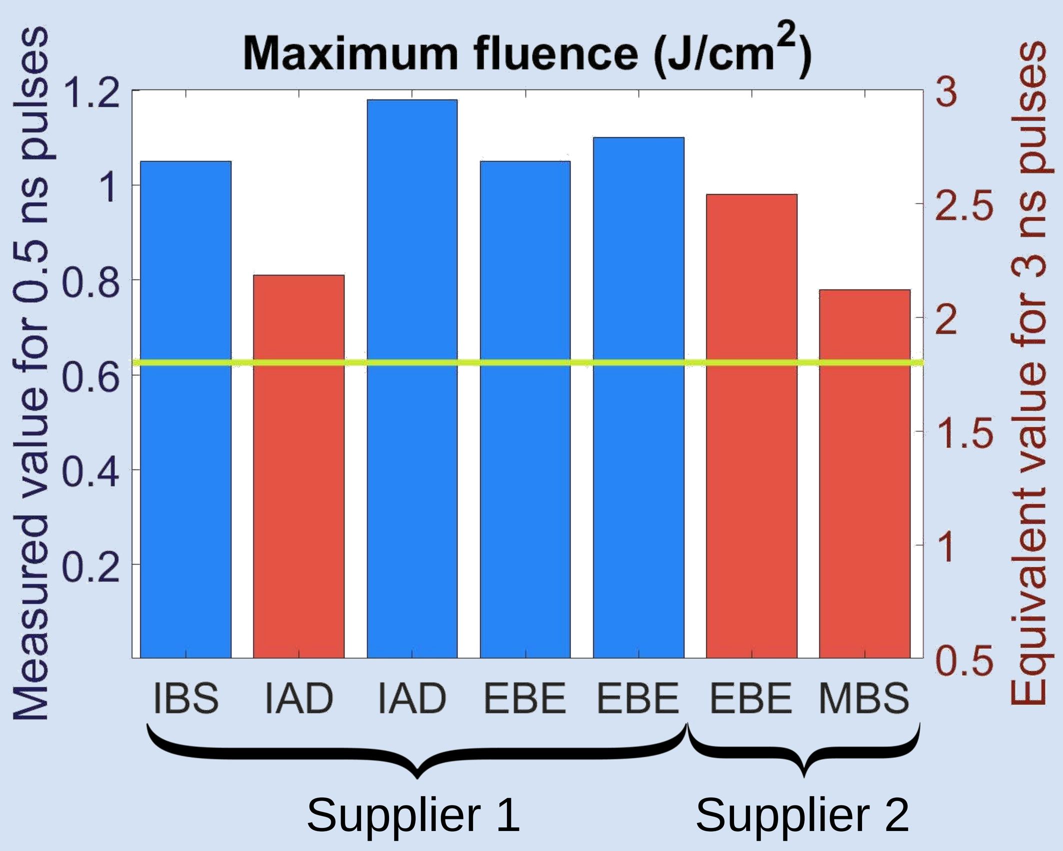


Figure 3: *Comparison of damage resilience of highly reflective coatings deposited by two different suppliers (Supplier 1 and Supplier 2) using a variety of deposition techniques (listed on the x-axis).*

Red bars represent samples where damage had occurred below the maximum available fluence.

Horizontal yellow line represents the minimum requirement for EPAC.

Results and Discussion

Of the 7 tested samples, only 3 showed damage below the maximum available fluence and even then the damage occurred above the maximum fluence specified for EPAC (Fig. 3). The coating deposition technique does not appear to have a clear influence on the damage and Supplier 1 was better performing overall.

The damage is most likely caused by defects in the coatings, as shown by the typical structure in Fig. 4 [2].

Further plans for investigations of coatings include:

- Comparing the reflectivity and surface scatter of samples
- Testing damage resilience of a wider variety of samples
- Testing performance for other types of coating (e.g. dual-band and anti-reflective coatings)

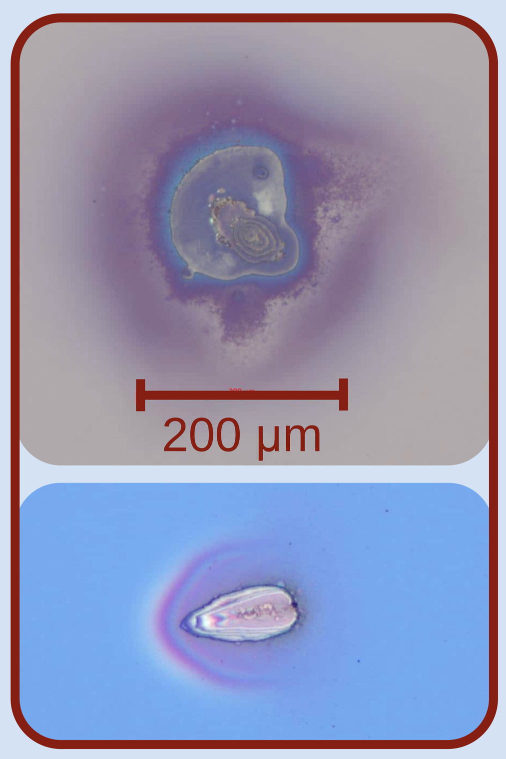


Figure 4: *Microscope view of damage sites: Supplier 2 EBE (top), Supplier 1 IAD (bottom)*

[1] Science and Technology Facilities Council, "Introducing The Extreme Photonics Applications Centre", https://www.clf.stfc.ac.uk/Pages/EPAC-introduction-page.aspx, Accessed: 24 Sept. 2021

[2] Stolz, Christopher J., and François Y. Génin. "Laser resistant coatings." Optical Interference Coatings. Springer, Berlin, Heidelberg, 2003. 309-333.