激光驱动微小碎片撞击效应及防护

Laser Driven Micro Flyer Hypervelocity Impact Effects on the Outer Surface of Spacecraft and Protection

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- Grants: Chinese National Basic Research Program 2010BC

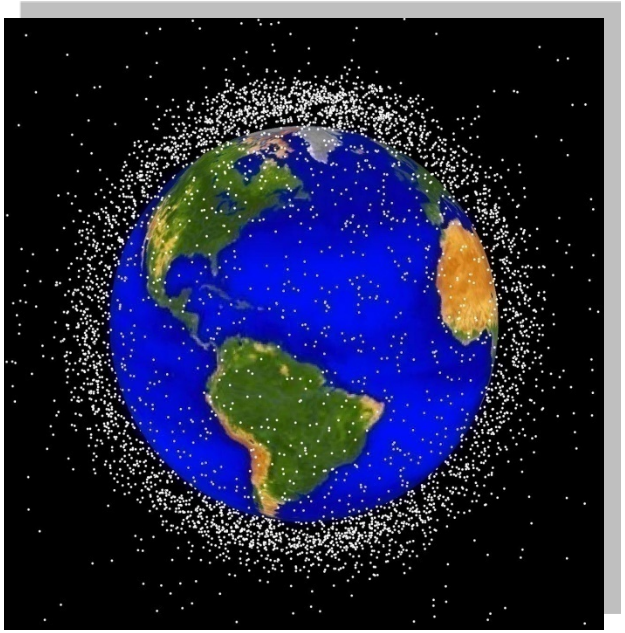
Outline

1. Backgrounds
2. Laser- driven Flyer technique
3. Hypervelocity Impact Effects
4. Protection Technique
5. Conclusion

1. Backgrounds

- Laboratory simulation of micrometeoroid/ orbital debris impacts at velocities 7km/s has long been accomplished by conventional accelerators(light-gas guns, plasma-drag accelerators)

  (Expensive, low shot repetition)



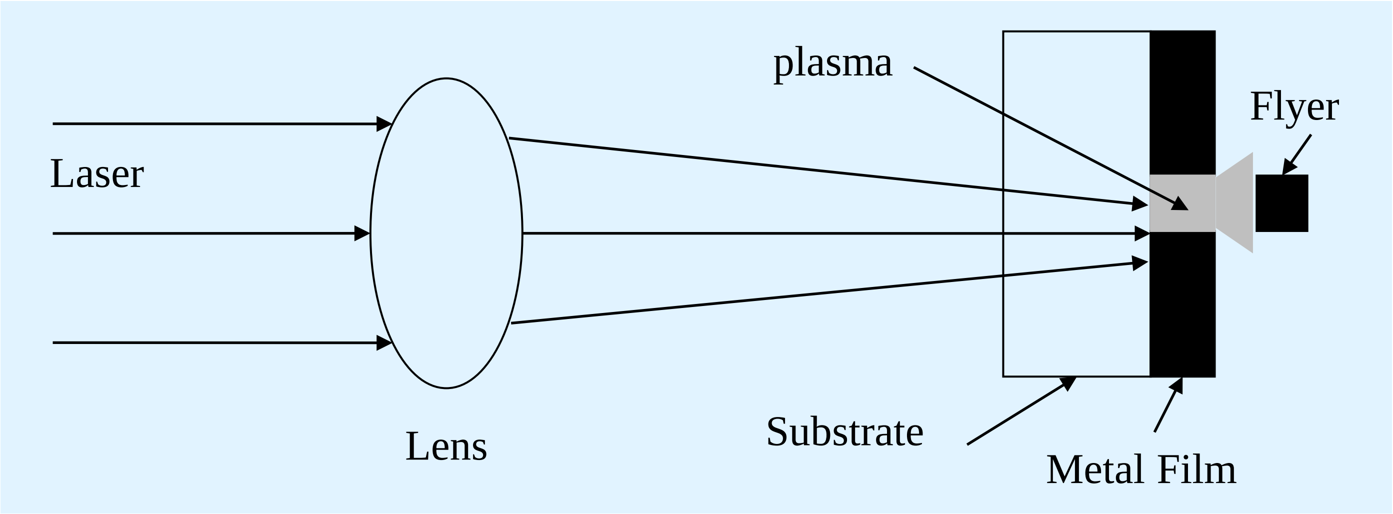
- Laser Driven Flyer(LDF)

  (Compact, repeatable,

  relatively inexpensive)

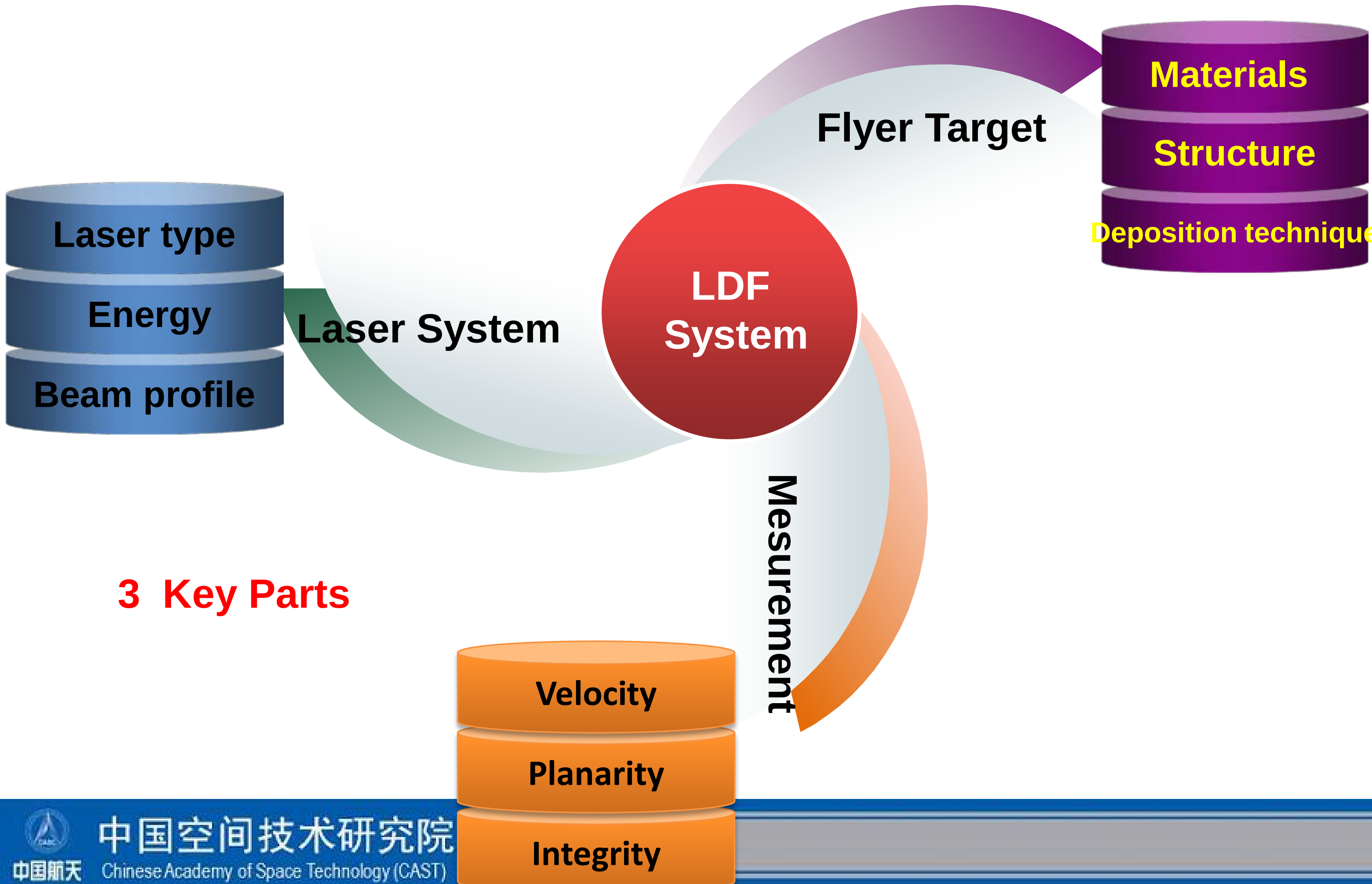
2. Laser-driven Flyer technique

- Simulate micro-debris (diameter: ~1mm， thickness: ~ several micrometers)



Schematic diagram of LDF in CAST

Laser-driven Flyer Experiment System

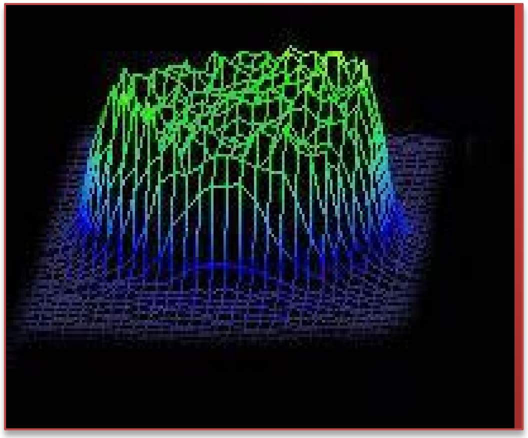


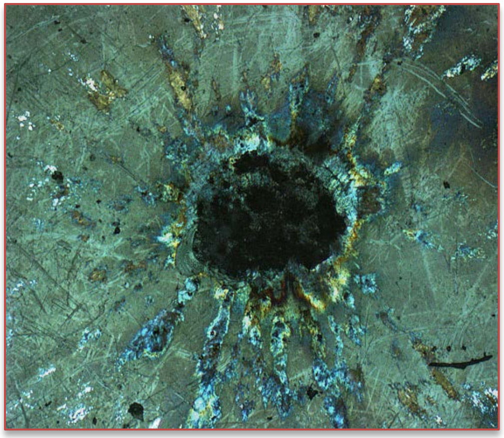
3 Key Parts

2.1 Laser system

- **Laser beam ("top-hat" profile is desirable)**

spatial profile of "top-hat" can easily produce plane shock wave, launch integrity and hypervelocity flyer, but "gauss" or exist strong spot can not obtain integrity flyer.

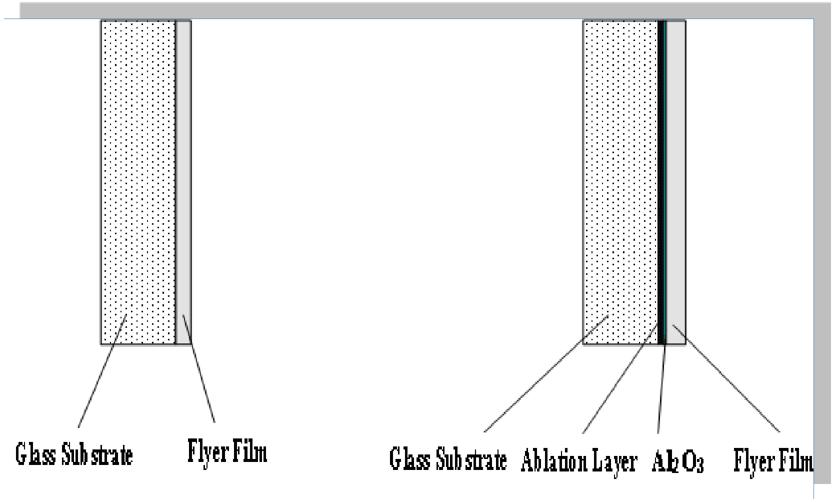




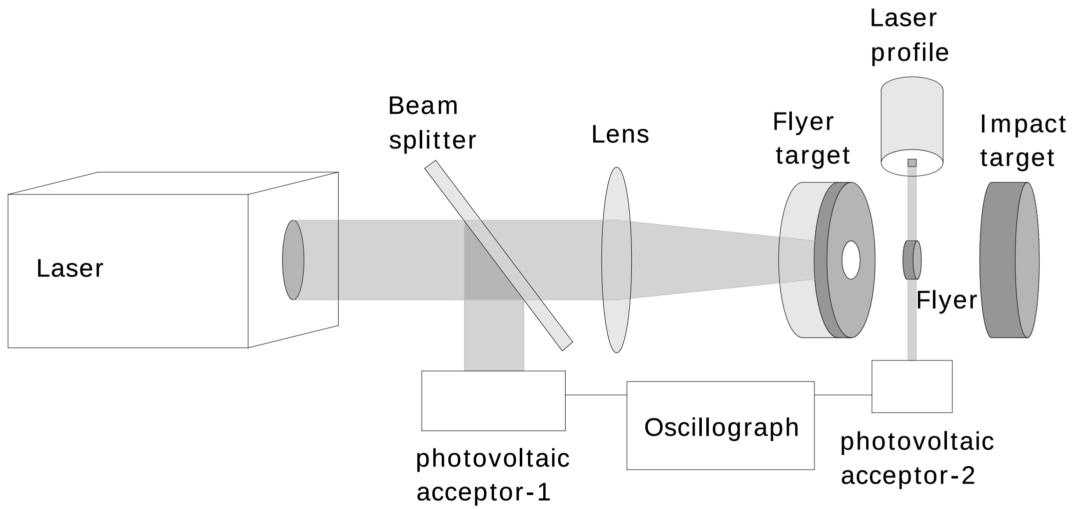
3D Beam profile

2.2 Flyer target

- Substrate materials：fused -silica or K9 glass
- Monolayer：AL
- Multilayer：Cr/AL
- Thickness of flyer film：3～10μm
- Deposition methods：magnetron sputtering，electron beam evaporation，ion beam sputtering



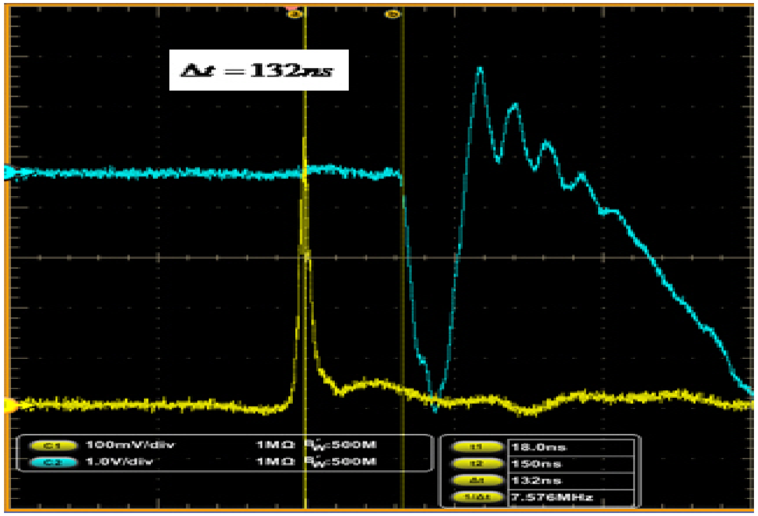
2.3 Flyer Measurement



- **Velocity measurement** **(not easy: small size and low mass flyer)**
  - **Laser profile velocity measurement system**
    - **Measurement error: <10% (if v<5km/s, the error is no more than 4%, and v~10km/s error ~9%)**
- **Oscillograph** **(Time resolution: 2.5GHz)**
- **Microscope** **(× 50)**

❖ Flyer velocity up to 10km/s

- **K9/Cr/Al (5mm/50nm/5μm) flyer target prepared using ion beam sputtering**
- **A flyer plate with diameter about 1mm and 5 μm thick was accelerated to 10.4km/s at 853mJ laser energy.**

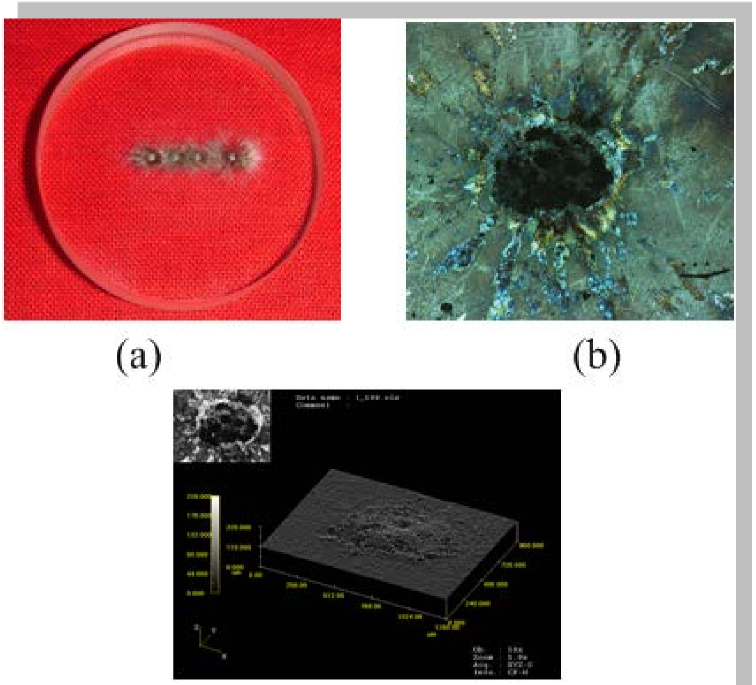


3. Hypervelocity Impact Tests

❖ 3.1 Optical glasses

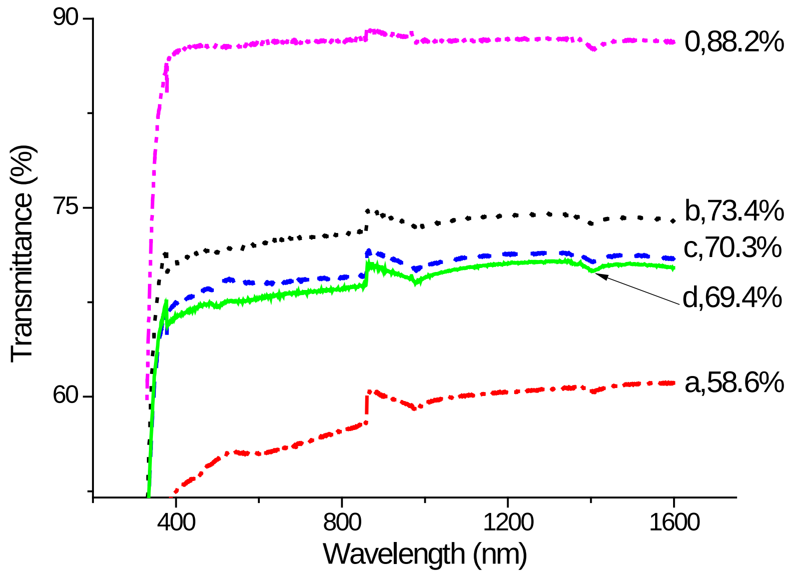
diameter mm	thickness μm	velocity km/s	
1	7	3.4	Single impact
1	7	4.2	Single impact
1	7	4.9	Single impact
1	7	5.5	Single impact
1.36	8	3.06	Single impact & Cumulative impacts

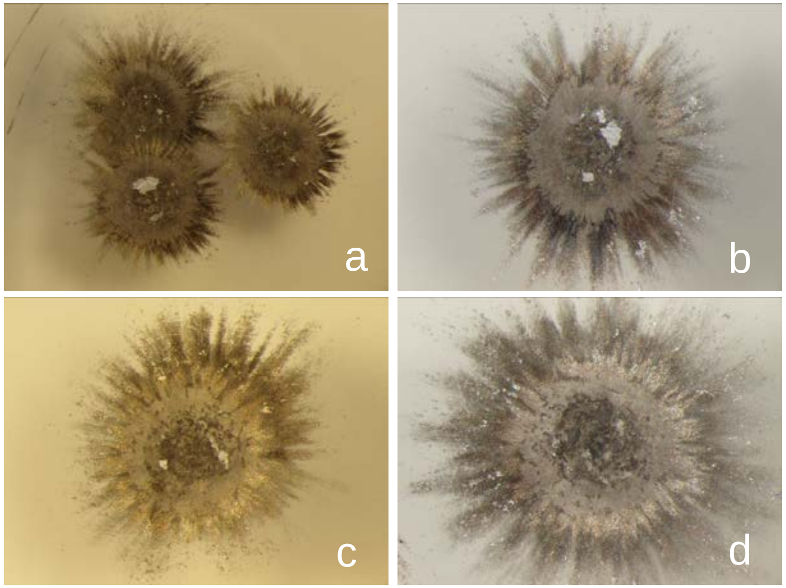
Impact parameter



(a) (b) (c)

Cumulative impacts





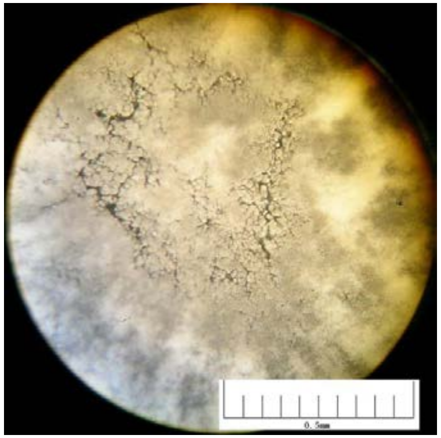
a: three shots; b:one shot;
c: two shots at the same position;
d: three shots at the same position

Single impact: transmittance degrades 23％～45％

Cumulative impacts : 16％～30％

(v=3.06km/s)

❖ 3.2 white paints (ZKS)

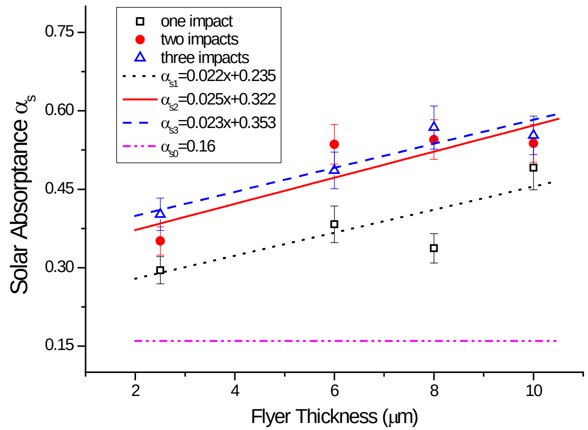


Typical optical image of paints

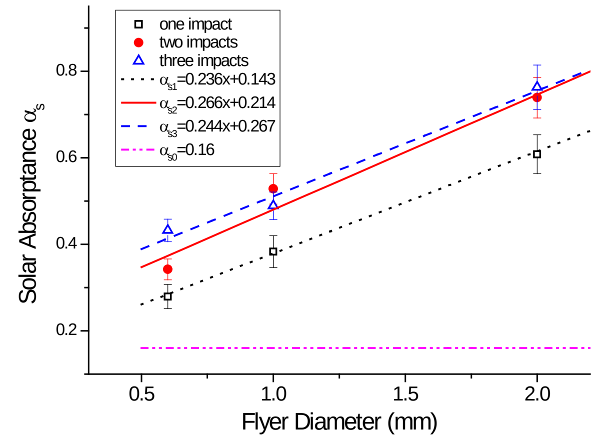
- **Solar absorptance α_{S0}=0.16**
- **Hemispherical emissivity ε_{H0}=0.90±0.02**

white paints (ZKS)

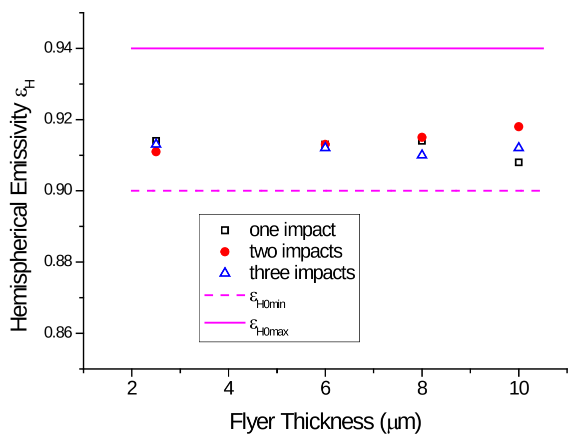
- Cumulative impacts
  - α_s rise from 0.16 to 0.60
  - Linear factor 0.023 in thickness
  - Linear factor 0.244 in diameter
  - ε_H : no change

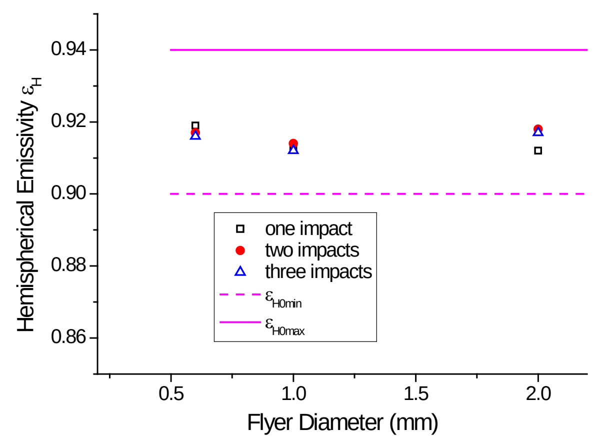


Flyer thickness



Flyer diameter

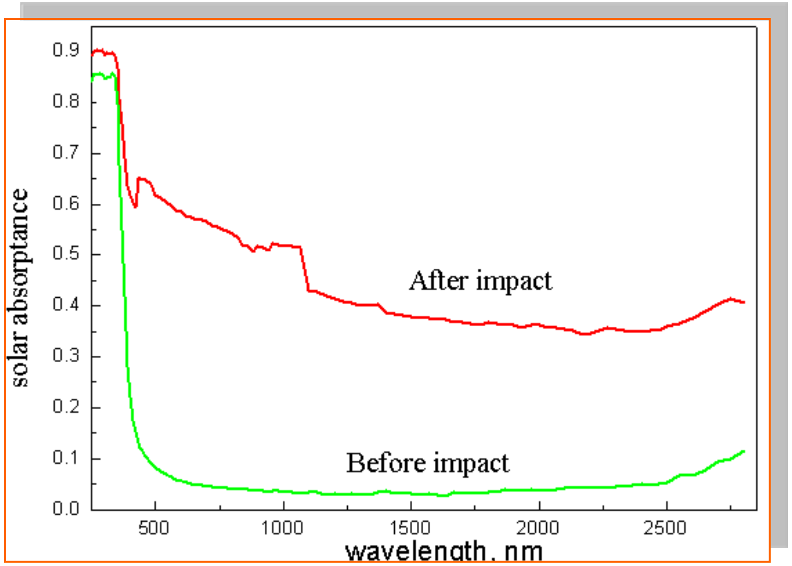


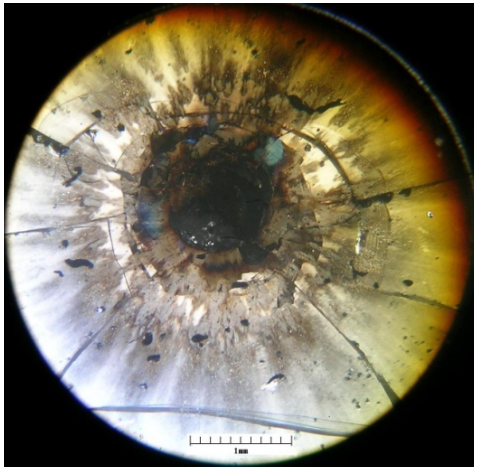


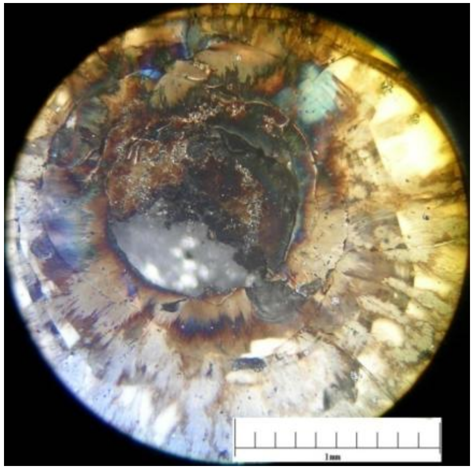
❖ 3.3 OSR (Optical Second Reflector)

(α_s /ε_H : thermal control capability)

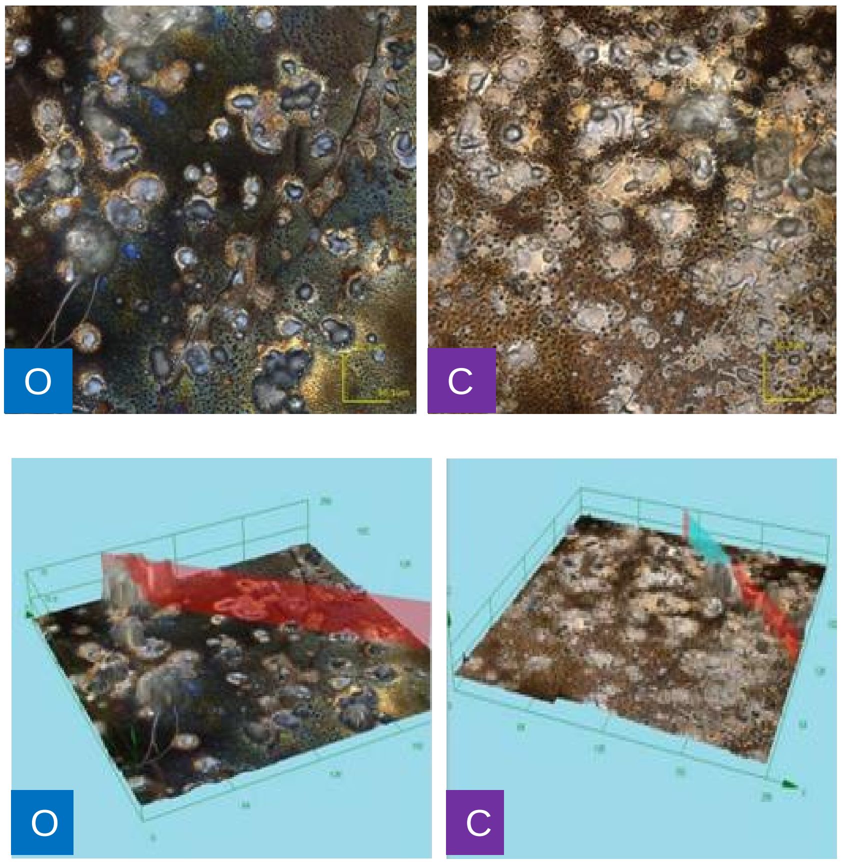
The solar absorptance of OSR rise after impact, but its emissivity without any change.







4. Protection Technique



❖ **Parameters of DLC (Diamond-like carbon) film**

- **thickness： 300nm**
- **hardness： >30GPa**
- **surface roughness < 20nm**
- **Transmitts： >80%**

- **Sample:**
- **O---OSR**
- **C---OSR（including DLC）**

4. Protection Technique

- **Diamond-like carbon (DLC) films**

have the unique combination of properties: high values of hardness, elastic moduli, electrical resistivity, and chemical inertness.

high values of hardness: crushed micro-debris to pieces.

The DLC films decreased the mechanical damages of surface, play an active role in protection from micro-debris .

5. Conclusion

- A laser-driven flyer ground simulation system has been developed for the launch of flyer with 1mm in diameter and a few μm in thickness to simulate space debris hypervelocity impact, achieving velocities up to 10km/s. Although the experimental results are semi-quantitative and primary, our focus is on demonstrating the suitability of laser-driven flyer technique for space debris hypervelocity impact damage, rather than drawing specific scientific conclusions from the data.

- Diamond-like carbon (DLC) films showed promise effect in protection from micro-debris impact on the outer Surface of Spacecraft.

Thanks for your attention

- Any questions?