Photonic Doppler velocimetry probe used to measure grain boundaries of dynamic shocked materials

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Grain boundary

[Image of grain boundary with scale bar indicating 30 µ]
Gas gun fires projectile from right to left. Projectile inters into catch tank where it hits the target material. Target undergoes shock compressions.
Photon Doppler Velocimetry (PDV)

Simplified schematic diagram of PDV showing the unshifted (reference) light in red, the Doppler shifted light reflecting off the moving surface in blue, and the combined unshifted plus shifted light in green.

\[ D = C \times 10^{-3} \]
Spectrogram of eight PDV data records, recorded on a single digitizer

data from 1-D shock compression of tin (12 GPa)
This metal underwent a double shock producing ejecta traveling faster than the moving surface.
Fiber Channel Organization
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Improved fisheye PDV probe design. Turning mirrors have been eliminated.
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PDV probe with Stereo Imaging

PDV fiber arrays are index matched to first fused silica lens
Bugeye probe could be used for stereo PDV and stereo imaging

The stop diameter determines the NA of collected light and also the depth of focus.

Assuming 24 mm diameter FOV at surface and 2.4 mm diameter bundle at 50 lp/mm. Resolve 200 µm at surface (5 lp/mm).

2 thin stop “washers” rest on top of prism.

Coherent bundles are translated 0.314 mm, so that the image areas overlap.

24 mm diameter zone for imaging (blue & black rays); 10x magnification.

F/# of surface collected light is 36.

Imaging stop (2.1 mm dia.).

5º stereo angle.
PDV Details

Ceramic mask for fiber arrays
(Photoveel II)
8 mm diameter,
1.5 mm thick,
126 µm tapered holes
Metrology

Reflected label off prism facet

90° azimuth
Future probe designs are for understanding how grain boundaries are affected by shocks.
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37 fiber 2D PROFA fiber array
10 μm core
37 μm core spacing

Gas Gun PDV microscope

Schott Coherent Bundle
0.9 mm active diameter
7.4 μm pixel size
18,000 pixels
121 resolution elements across the diameter,
Imaging designed for 800-900 nm wavelength band
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Gas Gun PDV microscope

37 fiber 2D PROFA fiber array
10 µm core
37 µm core spacing

Schott Coherent Bundle
0.9 mm active diameter
7.4 µm pixel size
18,000 pixels
121 resolution elements across the diameter,
Imaging designed for 800-900 nm wavelength band
Four 19-fiber PROFA arrays on same wafer as 189 individual 125 µm PDV fibers (12-channel MT ribbon connectors are used)
Two 19-fiber PROFA arrays on same wafer as 189 individual 125 µm PDV fibers (not all PROFAs and not all PDV channels are shown)
37 fiber 2D PROFA fiber array
10 µm core
37 µm core spacing
MTP connectorized into 12-fiber ribbons
$2,620

Another option:
61 fiber 2D PROFA fiber array (not shown)
10 µm core
37 µm core spacing
MTP connectorized into 12-fiber ribbons
$3,720
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Chiral Photonics,
61 fiber 2D PROFA fiber array,
10 µm core,
37 µm core spacing,
FC/APC connectors,
$5,865
Imaging stop, Ø 1.8 mm, sets depth of focus
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PDV stop, Set by NA of single mode fiber

Imaging stop, Ø 1.8 mm, sets depth of focus

1.200" 1.035"

SECTION A-A
Measuring dB loss at PROFA array interface to Fused Silica lens, while glue is setting.
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Gas Gun PDV microscope

1.035"

1.200"
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61 fiber 2D PROFA fiber array,
10 µm core,
37 µm core spacing,
FC/APC connectors,
$5,865

PROFA array pattern for 61 fibers

Pitch 37 µm
Average error in spacing 0.5 µm
Maximum error in spacing 1.8 µm
SCHOTT Leached Image Bundles
Flexible Imaging Applications

$875 per individual image bundle, $845 each when ordering 10 quantity.

<table>
<thead>
<tr>
<th>OD Outer Diameter (mm)</th>
<th>Length (mm)</th>
<th>Quality Area Diameter (mm)</th>
<th>Pixel Size (μ)</th>
<th>Pixel Count (k)</th>
<th>Distal Ferrule Diameter (mm)</th>
<th>Proximal Ferrule Diameter (mm)</th>
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<tr>
<td>1.05</td>
<td>760</td>
<td>0.9</td>
<td>7.4</td>
<td>18</td>
<td>1.22 x 5.60</td>
<td>1.22 x 12.80</td>
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</tbody>
</table>
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Scan of folded photo (should be no crease)
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Imaging system tilted at 18°

Gas Gun PDV microscope

Index matching gel required

Fused silica

17.47 mm

37 fiber 2D PROFA fiber array
10 μm core
37 μm core spacing

Schott Coherent Bundle (tilted relative to optical lens axis)
0.9 mm active diameter
7.4 μm pixel size
18,000 pixels
121 resolution elements across the diameter
Imaging designed for 800-900 nm wavelength band

(Light source, red filter, & polarizer not shown)
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Optomechanical design: monolithic approach

- Standard 2-axis x-y mount
- Imaging fiber: 760 mm (~ 2 ft) long fine Focus adjustment required
- Coarse alignment could be done mechanically, clocking is an issue
- Strain relief will be required for PROFA and imaging bundles
- Probe head threads in place with a locking ring
Monolithic design: customer concerns

9.1 mm to housing

Coarse alignment could be done mechanically

Imaging and PDV COTS lenses are consumable

PROFA multicore is consumable

Schott coherent fiber is removable
Photonic Doppler velocimetry probe used to measure grain boundaries of dynamic shocked materials.

IR microscope can be set to different magnifications
10 µm spot size from PDV fiber probe, seen at 1550 nm on the IR microscope

In this photo, the intensity of PDV spot is saturating camera. So, some spot size blooming occurs.
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37 fiber 2D PROFA fiber array
10 µm core
37 µm core spacing
MTP connectorized into 12-fiber ribbons
$2,620

50 mm f/3.8 lens

2 mm diameter coherent bundle

BK7 window,
3" diameter,
1/4" thick

Needs 100 mm EFL macro lens

8.0 mm diameter field of view

40X magnification

6.6"