Factors to Consider When Choosing a Probe for PDV

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Outline -- Factors to Consider When Choosing a Probe

Factors to consider

Probe types commonly used at LLNL

Conclusions
Factors to consider--initial stand-off

How far do you need to follow the surface?

A longer stand-off allows the probe to follow the surface a longer distance.

This is probably the single biggest factor.
Factors to consider--initial stand-off

Focusing probes have an efficiency curve that limits the depth of field.

We usually set the initial probe-to-surface distance with the focal point in front of the surface. This allows us to follow the surface a longer distance.
Factors to consider--initial stand-off

Long stand-off probes allow access for other diagnostics.
Factors to consider--surface tilt

We will initially install the probe at an angle to the surface normal if we know the surface will tilt during the measurement.

We generally try to stay within 10 degrees of the surface normal. We need a diffuse surface for this technique.

Place the probe so that the surface normal sweeps through the probe during the measurement.
Factors to consider--physical space

Short stand-off probes will not allow closely-spaced measurements if we do not exceed 10 degrees.
Factors to consider--physical space

Smaller diameter probes will fit into a smaller space but have lower efficiencies, which means less signal.
Factors to consider -- solid angle

A large solid angle collects more light, which means less laser power or compensates for low surface reflectivity.

Large solid angle

Small solid angle
Factors to consider--solid angle

A large solid angle allows more tilt

The red rays show the case for a specular surface, but the same principle applies to a diffuse surface.
Factors to consider--surface preparation

Specular surfaces generally go diffuse when shocked, so we often make a diffuse surface initially to avoid large drops in the signal returned to the probe. This also helps with surfaces that tilt during the measurement.

(higher peak brightness)

(bead blast or ball roll)
Factors to consider--spot diameter

The focal length of the lens affects the spot size.

Some measurements require high spatial resolution at shock arrival, which means you want a small spot diameter. Place the surface at the focal point to start the measurement.
Factors to consider--power budget

Historically, we use probes with $10^{-4}$ efficiency

The power budget for PDV is sufficient for probes with $10^{-4}$ efficiency

The circulator has a max power rating of 0.5 W

These detectors saturate at 2 mW

We order probes with BRs to match the surface return

2W Laser

Detector 2000 V/W

Digitizer 12 GHz

55 µW
Factors to consider--probe back reflection

It is important to have only a single source of undoppler-shifted light.

We use angled FC connectors everywhere (-60 dB).

We have used probes with BR ranging from 0.04 to $10^{-4}$.
Factors to consider--probe back reflection

LANL uses probes with very low back reflection and an external variable source of undoppler-shifted light.

They order probes with -60 dB back reflection.
240-mm focusing probe

Oz Optics designed and built a custom probe that matched the physical dimensions and optical efficiencies of our FP probes.

We quickly realized the advantage of buying probes rather than building them.

Initial stand-off is usually 250 mm.

Probe body is
15 mm dia x 40 mm

Lens dia = 12.5 mm
Focal length = 240 mm
Efficiency = $1.1 \times 10^{-4}$
BR = -40 dB
Spot dia = 90 µm

Oz Optics Part # LPF-OSP-1300/1550-9/125-S-8.7-240-25AC-40-3A-3-5
240-mm focusing probe

We use the 240-mm probes for cook-off experiments. 250-mm stand-off keeps the probes outside the heaters.
97-mm focusing probe

We use more 97-mm probes than any other size or type. We usually set the initial distance at 102 mm from the surface.

Probe body is
8 mm dia x 19 mm long

Lens dia = 5 mm
Focal length = 97 mm
Efficiency = 0.38 \times 10^{-4}
BR = -40 dB
Spot dia = 150 \mu m

97-mm focusing probe

![Diagram of 97-mm focusing probe with probes 1, 2, 3, and 4, and a graph showing velocity vs. time for probes vp1, vp2, vp3, and vp4. The graph indicates a peak velocity of 33 mm.]
5.5-mm focusing probe

We sometimes have very small packages that require many probes

Probe body is
1.5 mm dia x 10 mm long

Lens dia = 1.0 mm
Focal length = 5.5 mm
Efficiency = $4.1 \times 10^{-4}$
BR = -15 dB (= 4%)
Spot dia = 50 µm

Oz Optics Part # LPF-07-1550-9/125-S-5-5.5-1.01GR-15-3A-1-2
5.5-mm focusing probe

This experiment required 6 measurements within 21 mm

Velocity vs Time

Red = 1-3
Blue = 4-6

1.0 mm
0.5-mm proximity probe

A bare fiber makes an effective probe for short-distance measurements

- Spot diameter = 150 µm
- NA = 0.14
- BR = -15 dB = 4%
- Efficiency = $0.33 \times 10^{-4}$

A simple fiber connector makes a quick and easy probe

- FC/APC
- FC/U
- Fiber jumper
- 0.5 mm
0.5-mm proximity probe

Glue the fibers into different assemblies and polish the ends

Multiple fibers in a "puck"

Individual fibers glued into holes

SST capillary

0.5 mm

0.5 mm
0.5-mm proximity probe

Shock arrival measurement on a gas gun

7 fibers glued into a puck

100 ps standard deviation among 7 probes
0.5-mm proximity probe

- Individual fibers glued into holes
- SST capillary

Capillaries are made by Vita Needle Company
1/16” OD x 0.020” wall thk

- Velocity vs Time graph
  - Velocity (m/s)
  - Digitizer time (µs)
  - 0.0 to 3000
  - 6.0 to 8.5

- Distance vs Time graph
  - Distance (mm)
  - Digitizer time (µs)
  - 6.0 to 8.5
Factors to consider include: distance to follow surface, surface tilt, physical space, surface preparation, power budget

We use a wide variety of commercially-available probes for PDV 240 mm, 97 mm, 5.5 mm

A bare fiber at a distance of 0.5 mm makes an effective probe

Focusing probes can usually follow the surface for 15 - 30% of the initial probe-to-surface distance