Phase Doppler Interferometry Measurement of the Cloud Drop Number Distribution during RICO

Patrick Chuang
Univeristy California Santa Cruz

Overview

- Scientific Goals
- Technological Goals
- Overview of PDI

Scientific Goals

1. To make high accuracy measurements of the cloud drop spectrum.

2. To study the large drops critical for collision-coalescence.

Scientific Questions

- What is the concentration of those drops that initiate collision-coalescence, i.e. drops with D_p > 50 um?
- Where are they located in small cumulus clouds? Cloud top? Cloud edges? Updrafts? Downdrafts? Everywhere?
- What is their relationship to other cloud properties (e.g. turbulence, vertical velocity, LWC)?
- What does this tell us about the mechanisms of their formation?

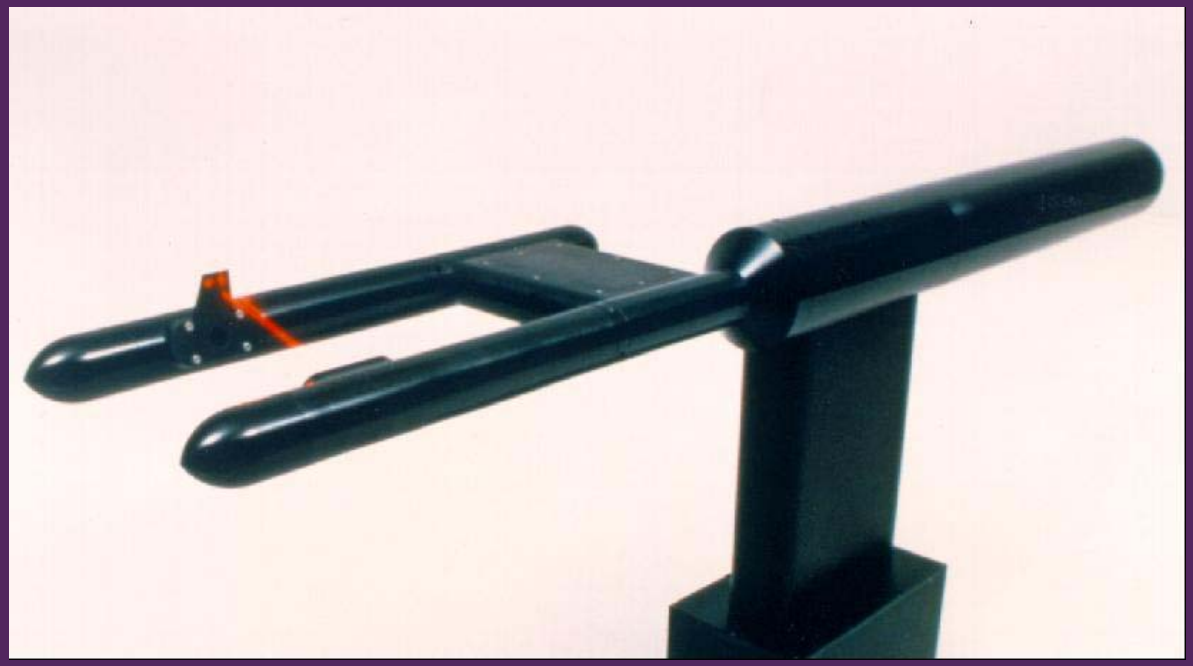
Technological Goals

- How does this new instrument compare with other instruments under flight conditions?
  - cloud droplet number distribution
  - liquid water content

Instrument Specifications

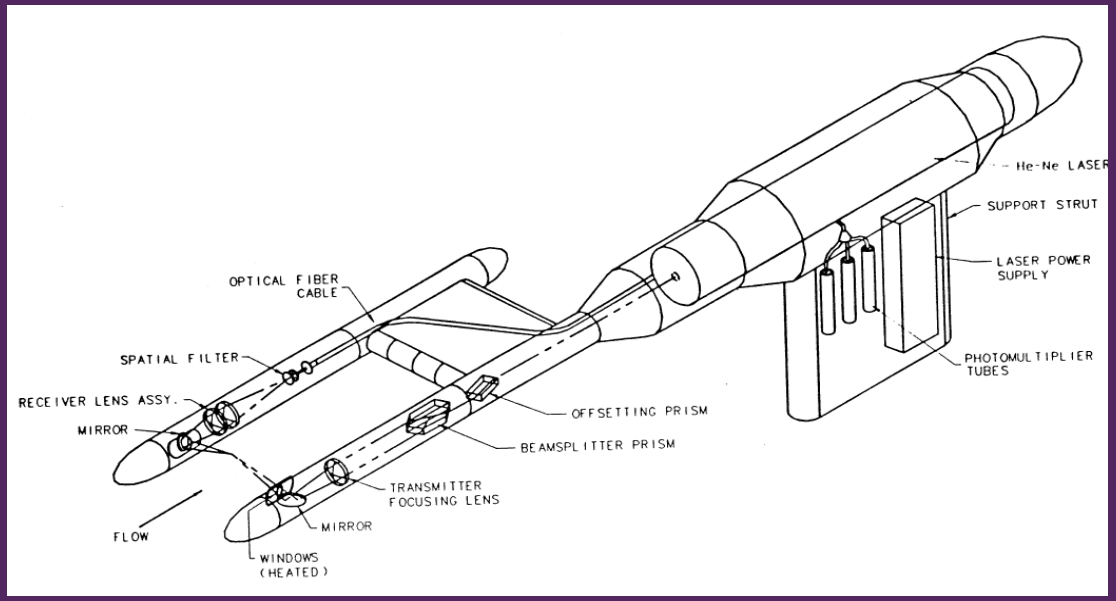
- Droplet sizing
  - size range 2 to 200 um (conservative)
  - min. dynamic range of 100:1
  - accuracy ±0.5 um absolute
- Concentration
  - 5% uncertainty for each size bin (due to view volume uncertainty)
  - View volume is calculated in near real-time

- Drop Velocity
  - nominal velocity range ±1 m/s in direction of aircraft travel
  - user-adjustable between ±0.1 to ±5 m/s.
  - accuracy 0.1% of full scale
- View volume
  - max. target area (perpendicular to aircraft travel) of 5 mm x 5 mm, adjustable
  - view volume thickness ~ 0.1 mm (minimize coincidence)
- Coincidence
  - can distinguish presence of multiple particles
  - can measure drop properties even if two are coincident but not completely overlapping.



Old PDI probe for aircraft icing use. Large He-Ne laser to be replaced by much smaller solid state laser.

Previous wind tunnel testing of this geometry shows no flow disturbance in the vicinity of the view volume



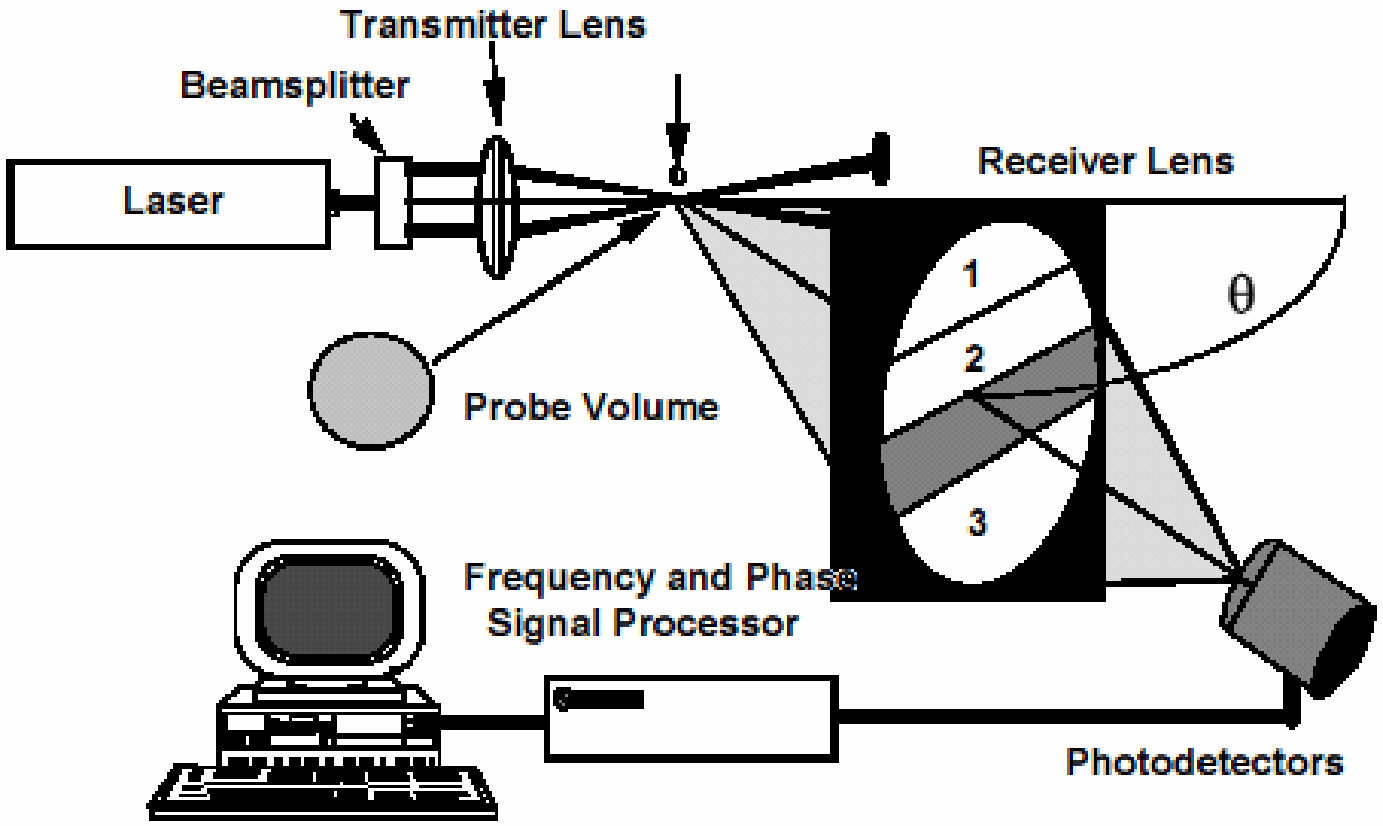


Figure 3: A typical PDI instrument setup.

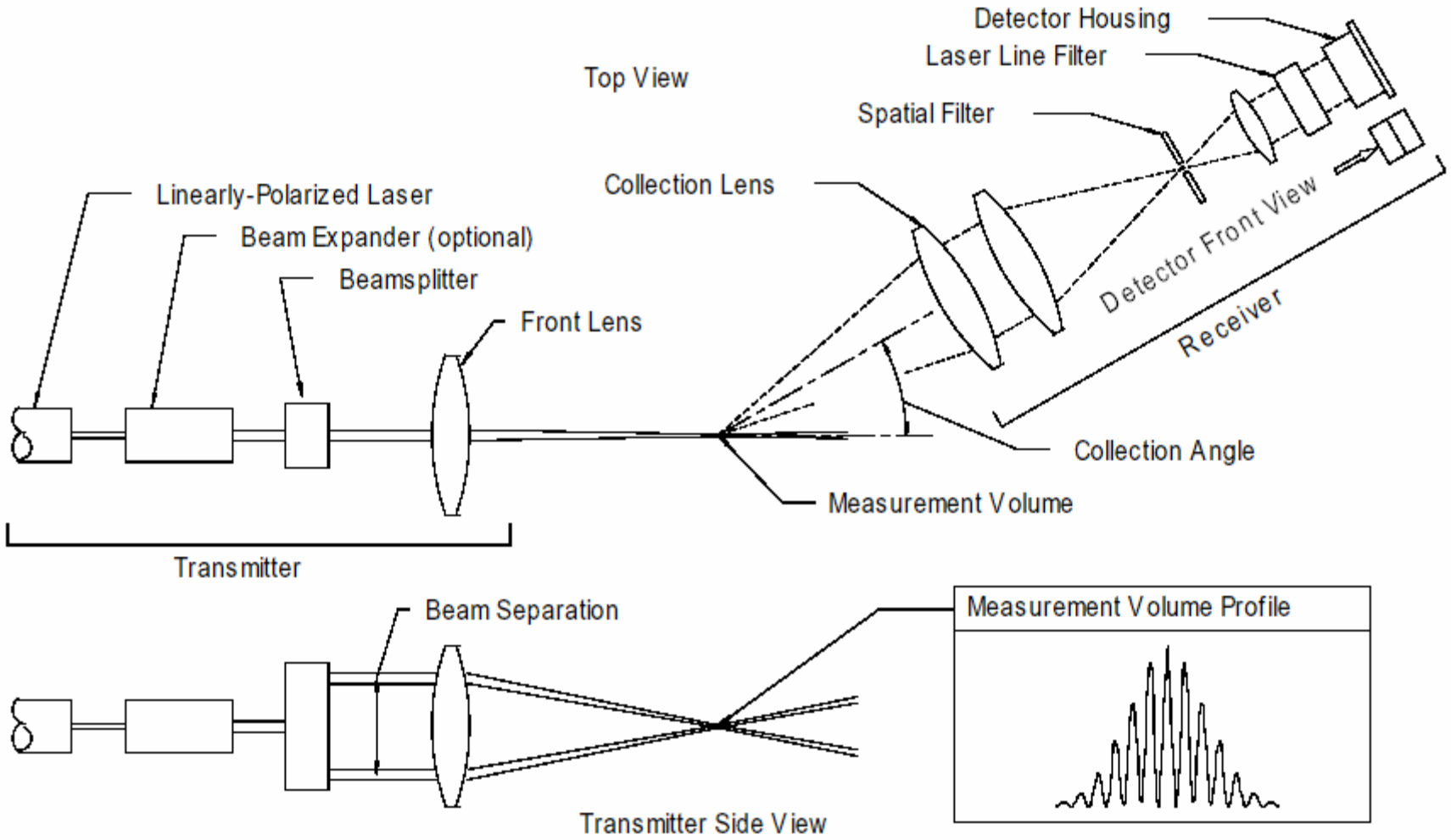
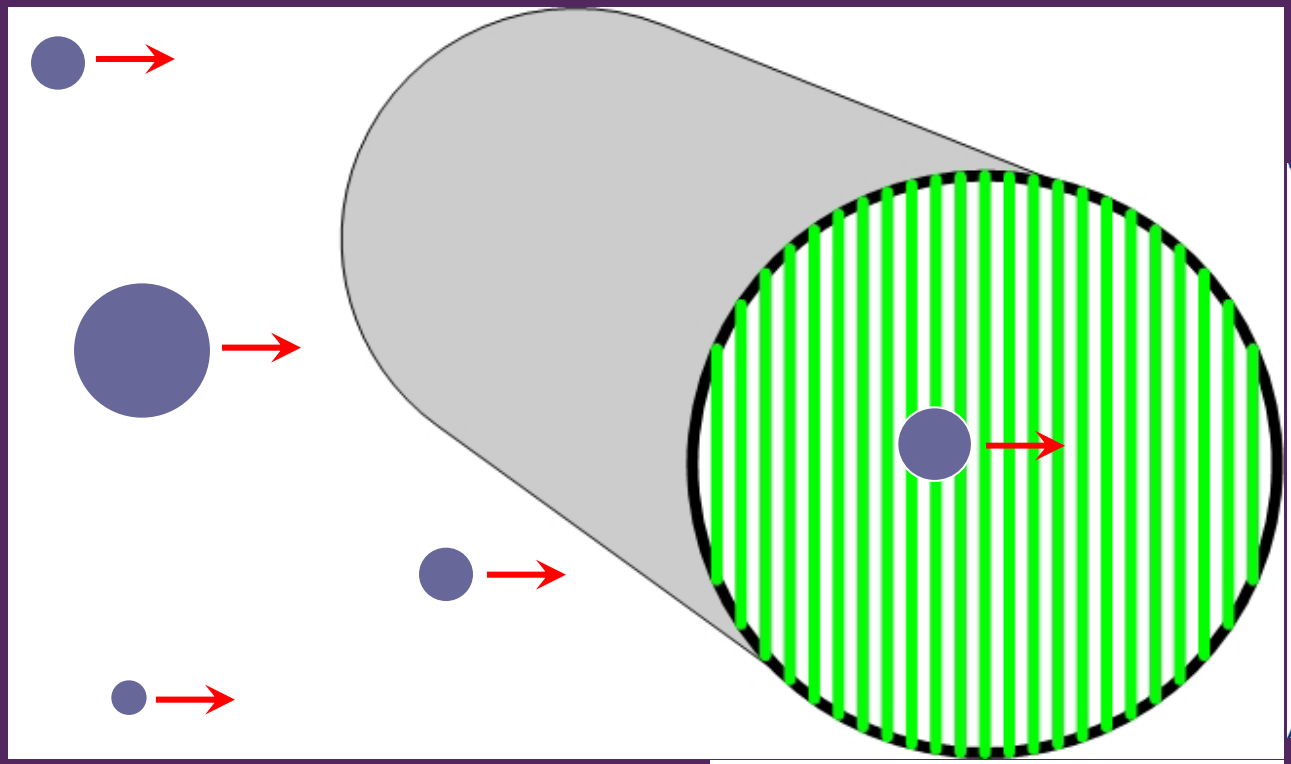
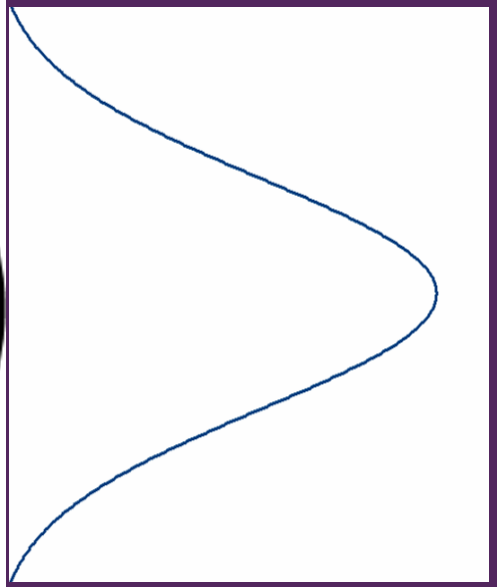
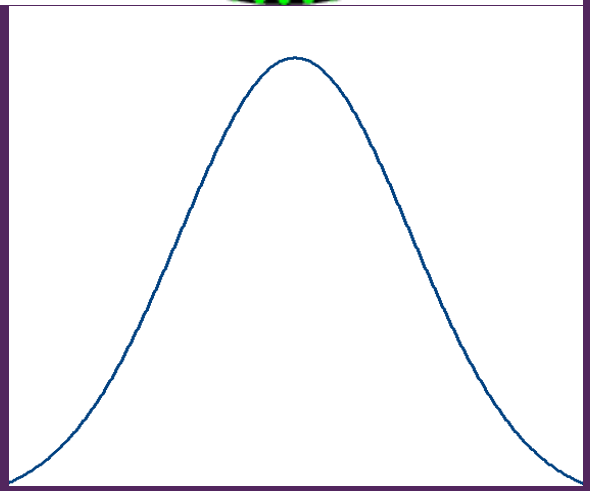
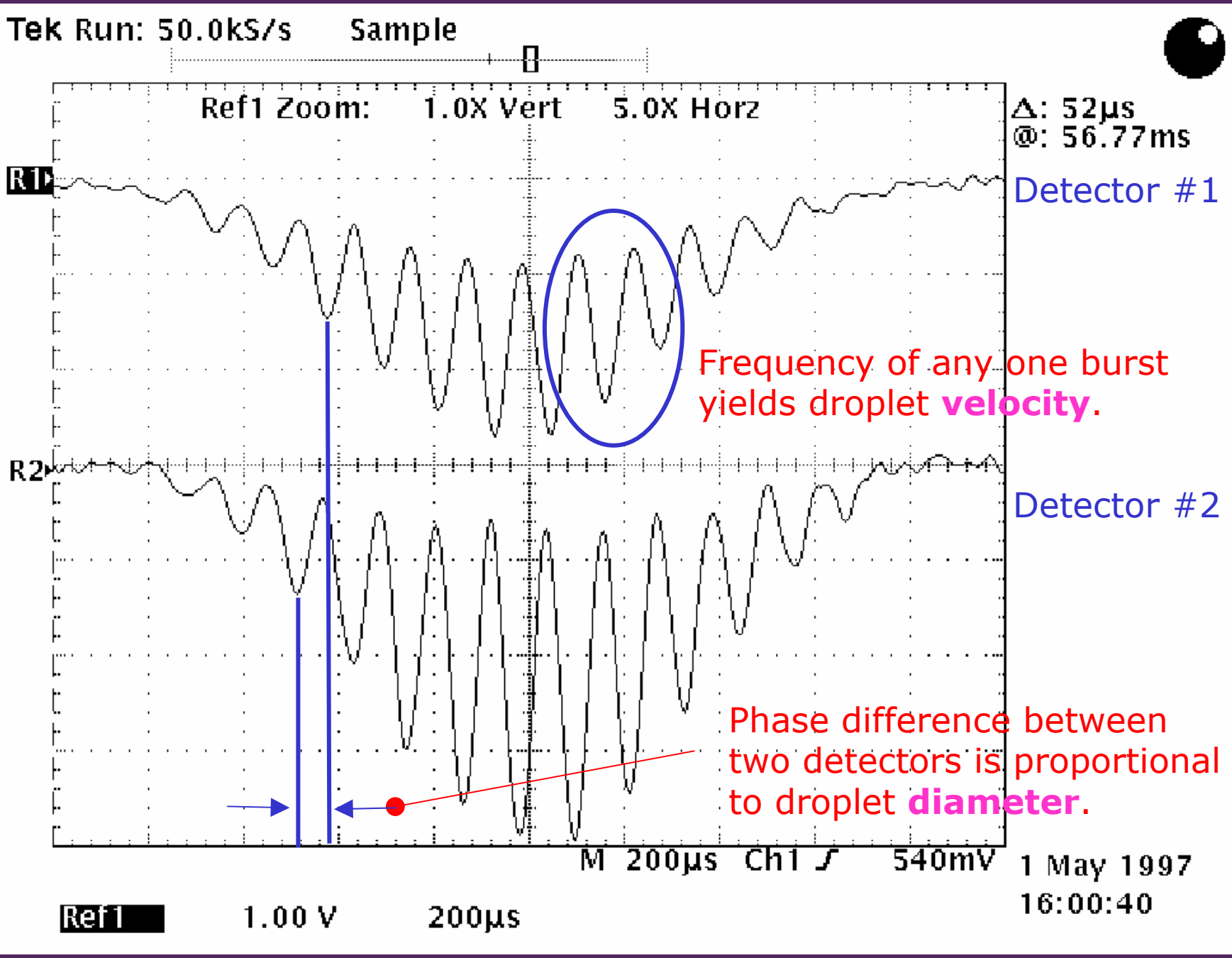


Figure 1-1: PDA system optical arrangement




Intensity


Intensity

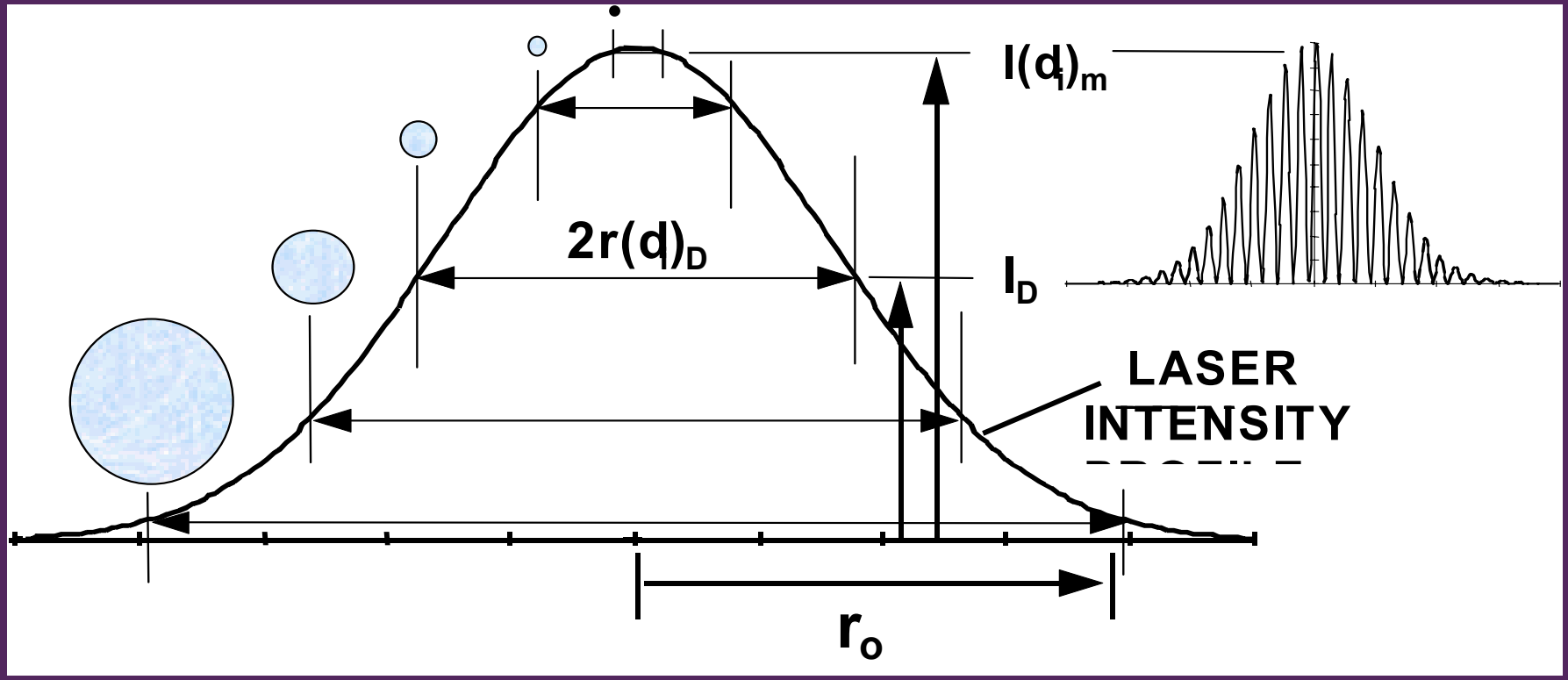

Tek Run: 50.0kS/s Sample
Ref1 Zoom: 1.0X Vert 5.0X Horz
Δ: 52µs
@: 56.77ms
R1
Detector #1
Frequency of any one burst yields droplet velocity.
R2
Detector #2
Phase difference between two detectors is proportional to droplet diameter.
M 200µs Ch1 ∫ 540mV
1 May 1997
16:00:40
Ref1
1.00 V
200µs

Limitations:

- Technique only works for spherical drops of known refractive index.

Advantages:

- Drop diameter and velocity measurements depends fundmentally on *frequency* (instead of amplitude), which is easy to measure accurately.



View volume is drop size dependent. This is determined in near real-time (every ~10^2 drops) by looking at (a) number of scattered fringes and (b) signal amplitude.