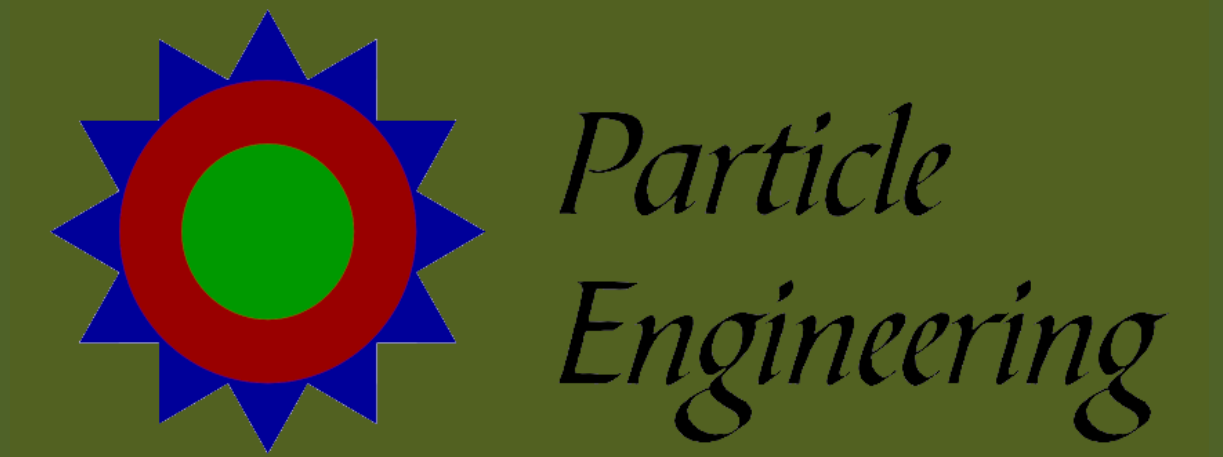


# A Continuous, Monodisperse Propellant Microdroplet Stream as a Model System for Laser Analysis for Examining Mass Transfer in Metered Dose Inhaler Sprays

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## Introduction

Drug delivery from MDIs is influenced by the diameter and velocity of the droplets in the propellant spray. Typically, an actuation from an MDI produces a spray that lasts only for a fraction of a second, making it difficult to study the transient heat and mass transfer processes that control droplet evaporation. Here we present a propellant droplet generator that can be used to produce a continuous, monodisperse droplet stream which can be studied for extended periods of time by laser light scattering. The droplet generator uses the vibrating orifice principle (1) and is integrated into a custom liquid feed system for use with high propellant pressure.

## Method and Materials

The droplet generator creates a liquid jet via a pressure drop,  $\Delta p$ , across an orifice with diameter,  $D_o$ , and discharge coefficient,  $C$ . The volume flow,  $\dot{V}$ , for a propellant with density,  $\rho$ , is given by:

$$\dot{V} = C \frac{\pi D_o^2}{4} \sqrt{\frac{2\Delta p}{\rho}} \quad (1)$$

If an external disturbance with frequency,  $f$ , acts on the jet, it disintegrates regularly into individual droplets with diameter,  $D_p$ :

$$D_p^3 = \frac{6\dot{V}}{\pi f} = C \frac{3D_o^2}{2f} \sqrt{\frac{2\Delta p}{\rho}} \quad (2)$$

The generator must be operated at pressures above the vapor pressure of the propellant and in a frequency range of approximately (2):

$$\frac{4\dot{V}}{7\pi D_o^3} \leq f \leq \frac{4\dot{V}}{3.5\pi D_o^3} \quad (3)$$

Normalized initial spacing,  $x_0$ , for the droplet can be calculated using,

$$\frac{x_0}{D_p} = \frac{V}{f D_p} = \left( \frac{4C^2 \Delta p}{3\rho \pi D_o^2 f^2} \right)^{1/3} \quad (4)$$

The propellant droplets were probed using either an argon ion laser (Innova 70, Coherent, Santa Clara, CA, USA) operated at a wavelength of 514.5 nm, or a diode laser (Lasiris, Coherent, Santa Clara, CA, USA) operated at a wavelength of 680 nm.

Fraunhofer diffraction theory was employed to calculate the droplet diameter from the circular fringe pattern (3). By locating the maxima and minima of each fringe pattern, and having the frequency and configuration of the setup, it is possible to determine the size of the droplets. Moreover, by knowing the distance between the horizontal lines in Figure 5, and using diffraction grating theory, spacing between droplets can be achieved.

## Results

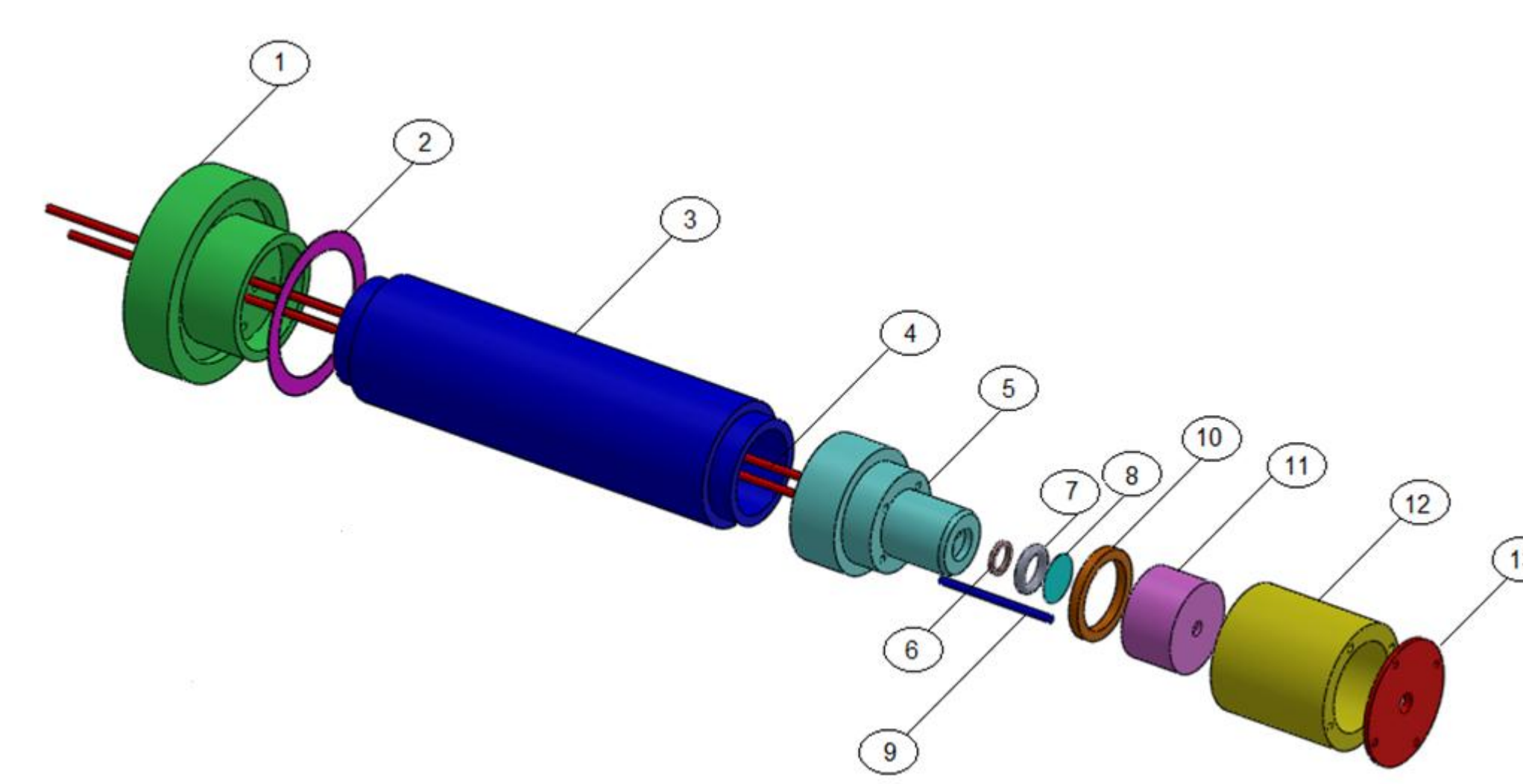


Figure 1: Droplet Generator Design

1	Base
2	Gasket
3	Tube
4	Capillary
5	Orifice Cup Holder
6	Frit
7	O-ring
8	Orifice Plate
9	Spring Contact
10	Piezoceramic
11	Orifice Cup
12	Dispersion Cup Body
13	Dispersion Cup Top



Figure 2: Finished Generator

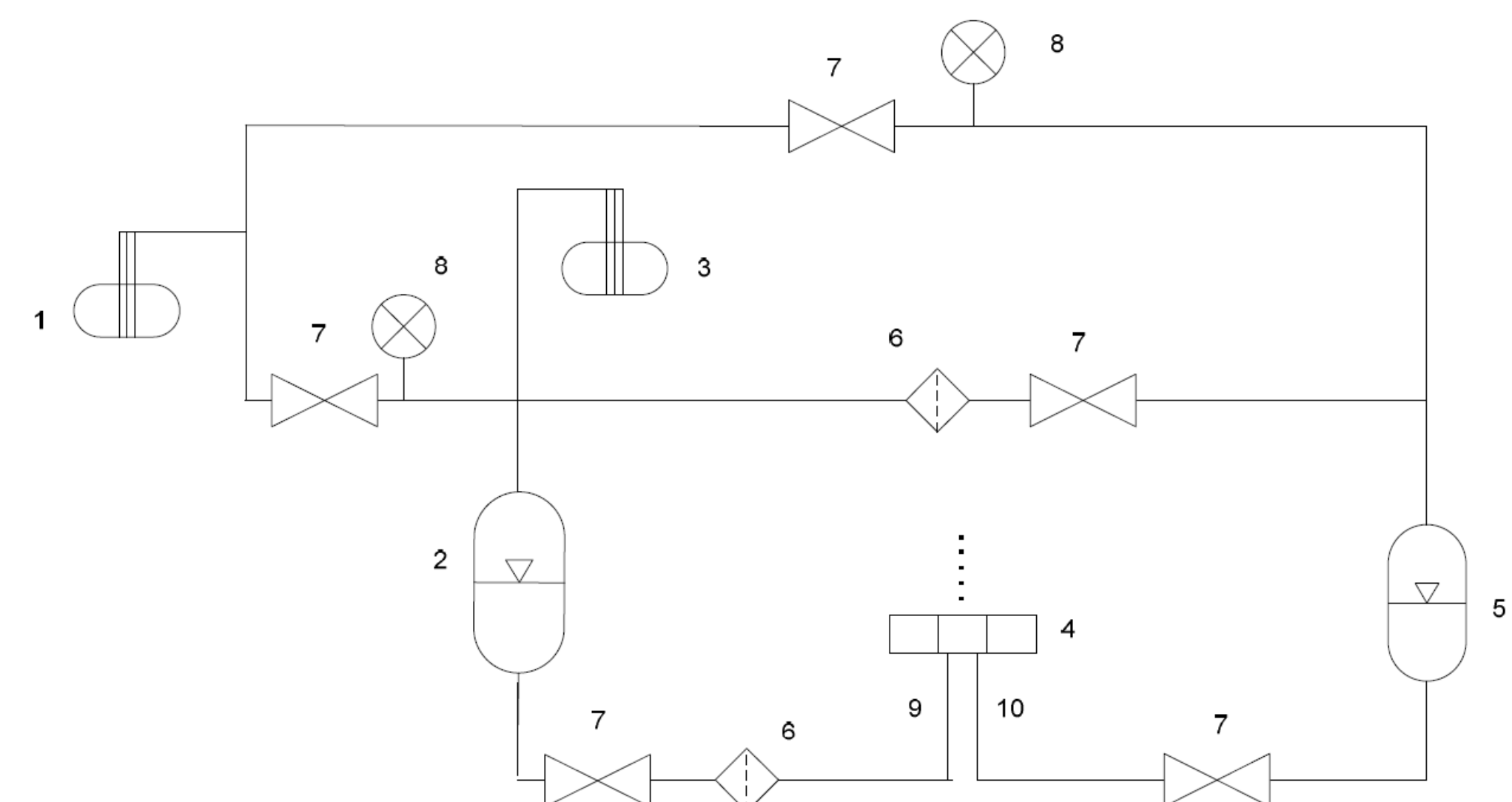


Figure 3: High Pressure Propellant Feed System

1	Nitrogen Supply
2	Reservoir
3	Propellant Supply
4	Droplet Generator
5	Drain Reservoir
6	Filter
7	Needle Valve
8	Pressure Gauge
9	Feed Tube
10	Drain Tube

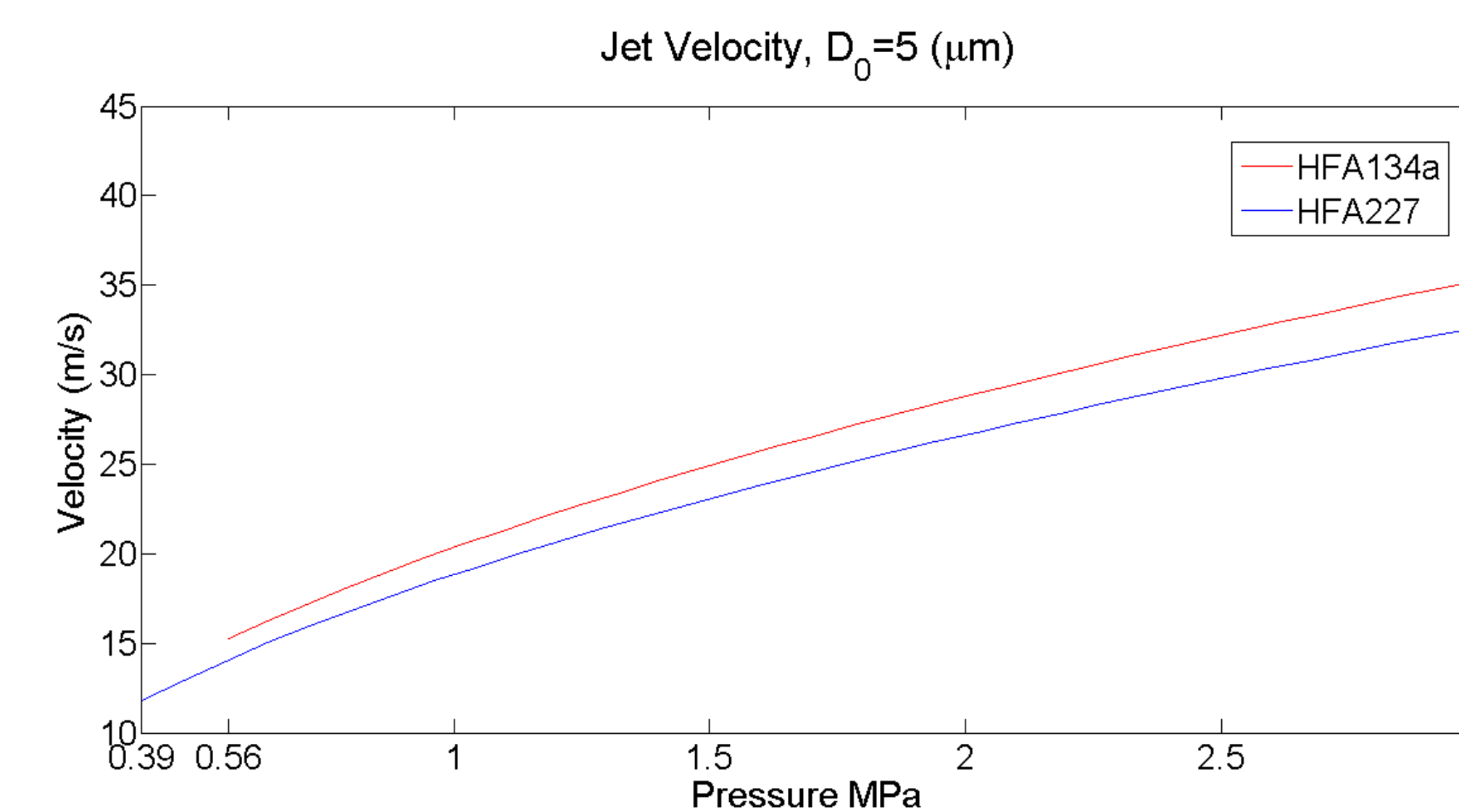


Figure 4: High pressure system allows high initial jet velocities, i.e., realistic droplet velocities.

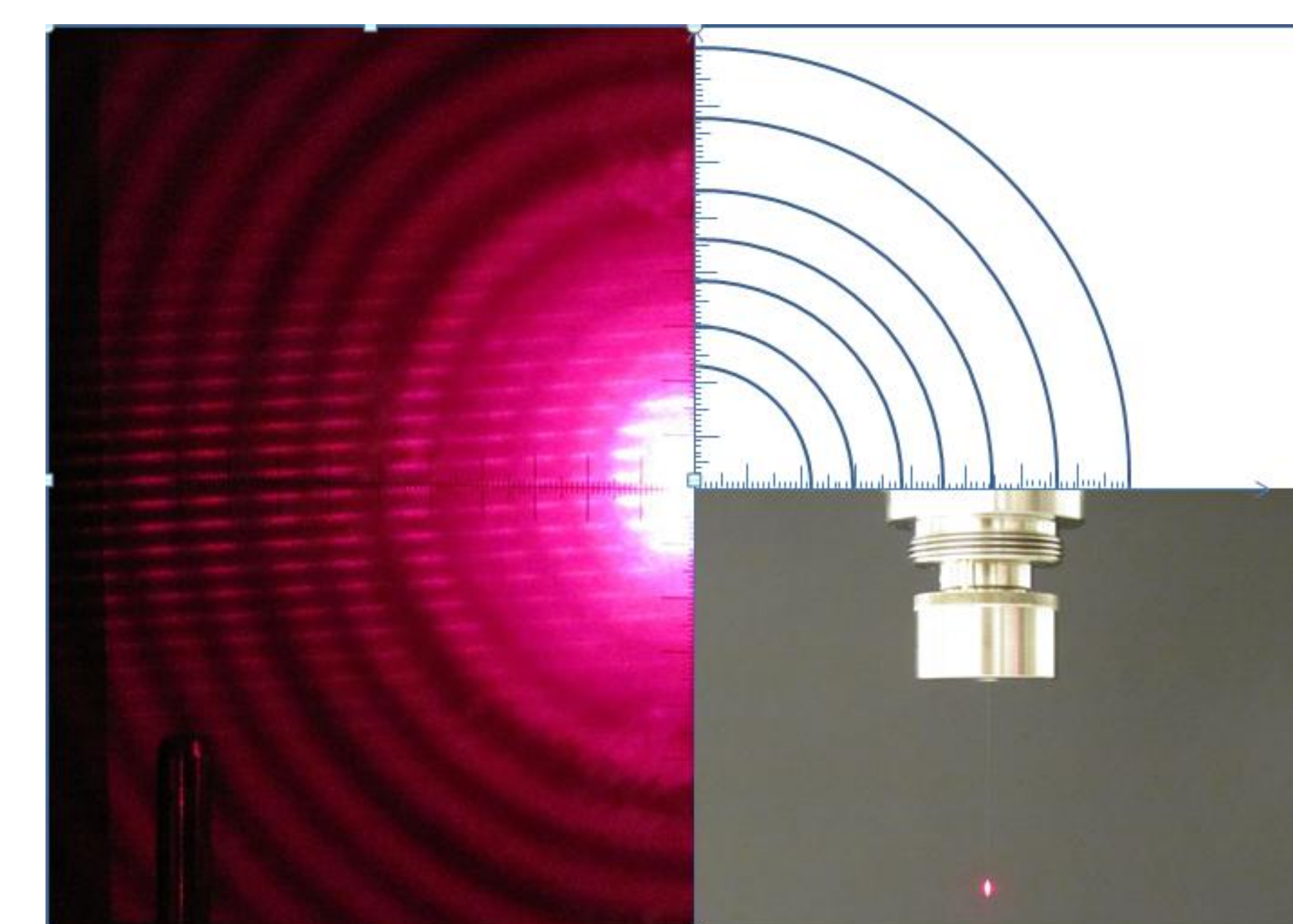


Figure 5: Stable Light Scattering Pattern.

- Proves monodisperse droplet production
- Remains stable for more than 1 hour
- Achieved for various droplet diameters (10 - 50  $\mu\text{m}$ )
- Ring spacing provides droplet diameter
- Horizontal line spacing provides droplet spacing

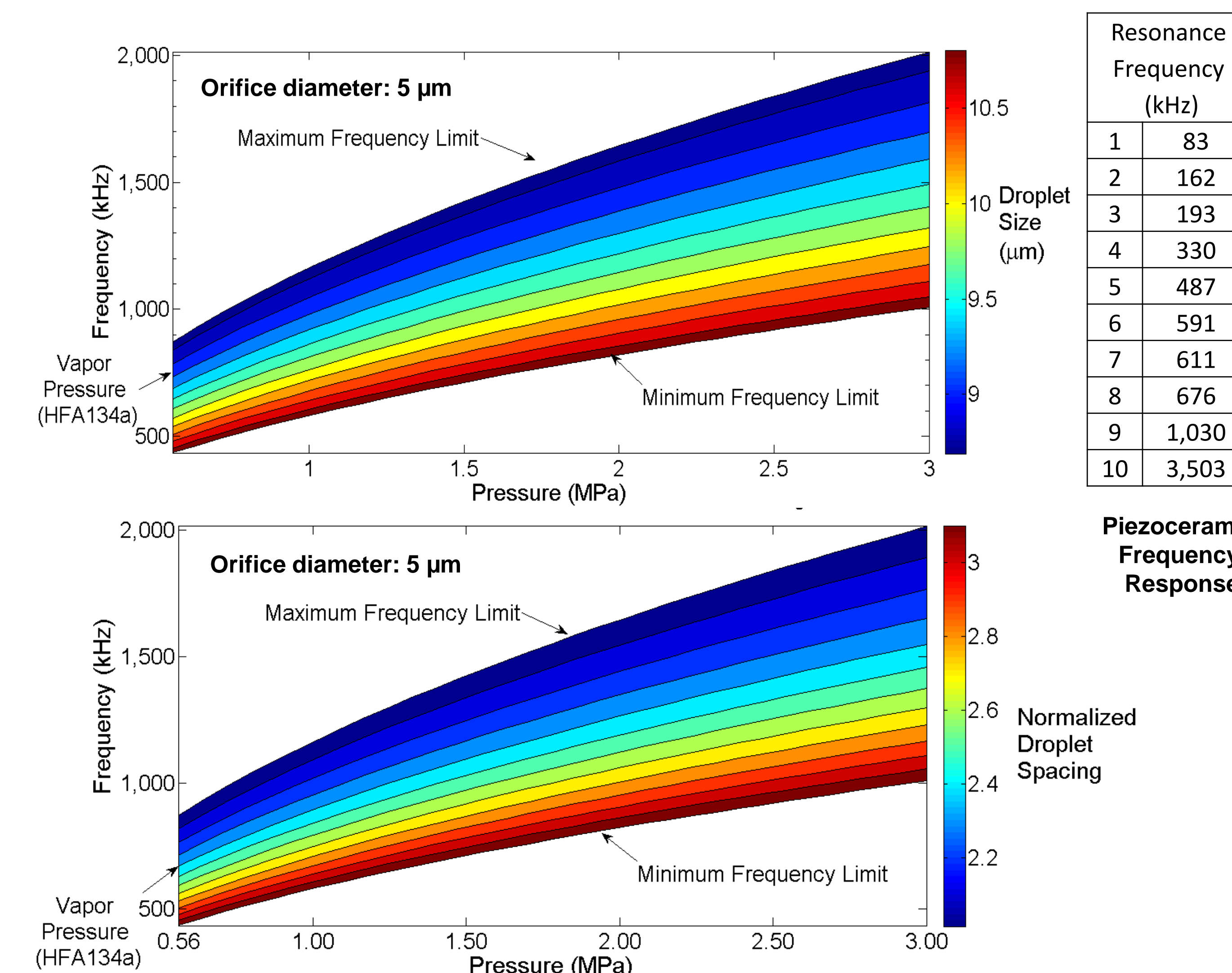


Figure 6: High excitation frequency allows realistic droplet diameters.

## Conclusion

Monodisperse droplet chains of high pressure propellants can be produced by controlled disintegration of liquid jets with a custom vibrating orifice generator.

The generator is capable of producing droplets with diameters and velocities similar to droplets generated in commercial MDIs (4).

The propellant droplets can be produced for extended periods of time making it a suitable model system for the study of heat and mass transfer in propellant sprays.

Laser light scattering patterns provide droplet diameter and velocity as a function of distance from the generator, which can be used to calculate droplet diameter as a function of time, i.e., evaporation rates.

The new monodisperse droplet generator will be utilized to develop an idealized experimental model for the study of propellant sprays.

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