Self-mixing Diode Laser Interferometry for Velocity Measurements of Different Targets

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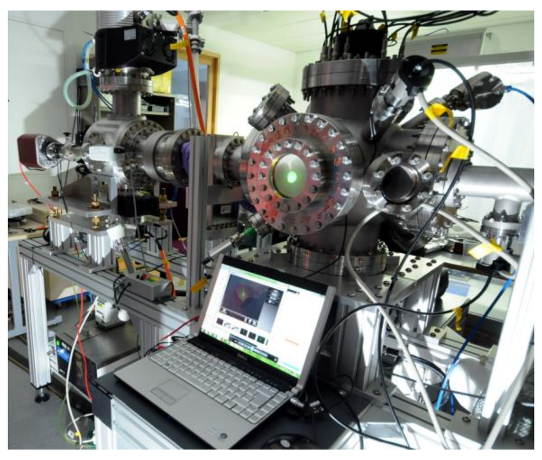
Abstract

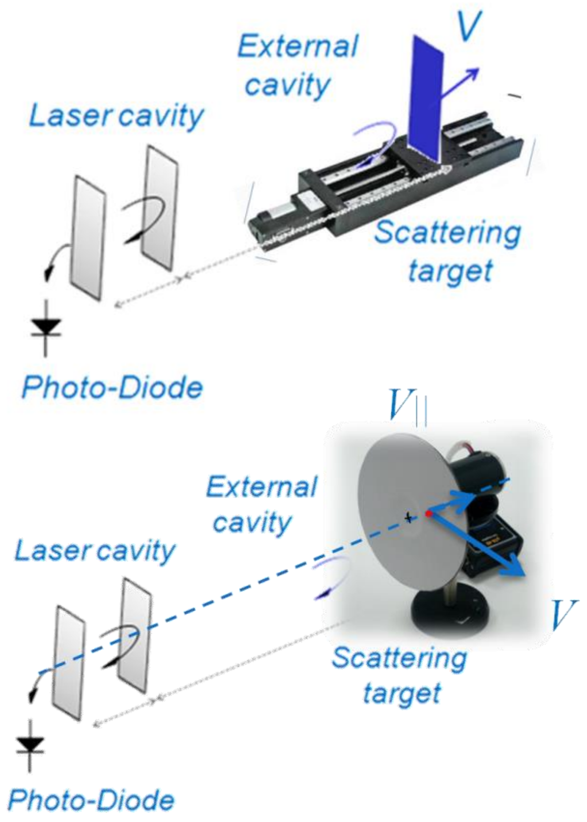
Supersonic gas jets can be used as a profile monitor for charged particle beams, as well as a cold target for collision experiments. For the optimisation of these experiments, it is important to know the velocity and density distribution of the jet. In these applications, gas jet velocities can be up to 2,000 m/s. A diode laser velocimeter based on the laser self-mixing method is currently being developed as an easy to build and compact alternative measurement technique. It is a self-aligning device where the laser is both, transmitter and receiver of the signal and a promising way for a complete characterisation of the gas jet parameters. Here, the heterodyne principle, the design of the laser diode velocimeter are first discussed before initial results from measurements are shown.

The Task

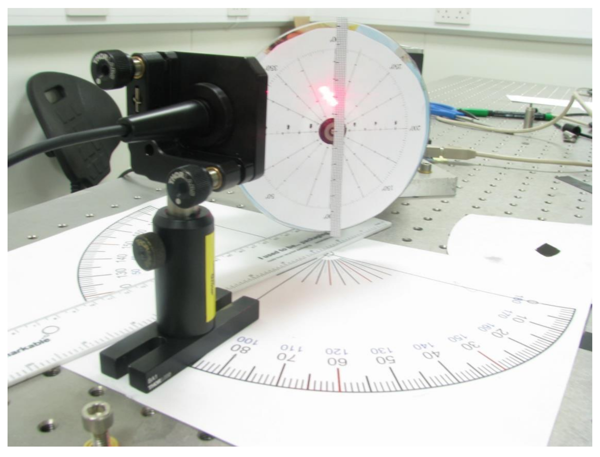
Gas targets are important for a number of accelerator-based applications. Detailed information about the gas jet is important for its optimization and the quality of the beam profile that can be measured with it.

- in-detail characterization of the gas jet,
- *Gas: Ar, N_2, He*
- *Velocities: 100-2000 m/s*
- *Density:* $10^9 - 10^{12}$ particles/cm^3
- compact and cheap



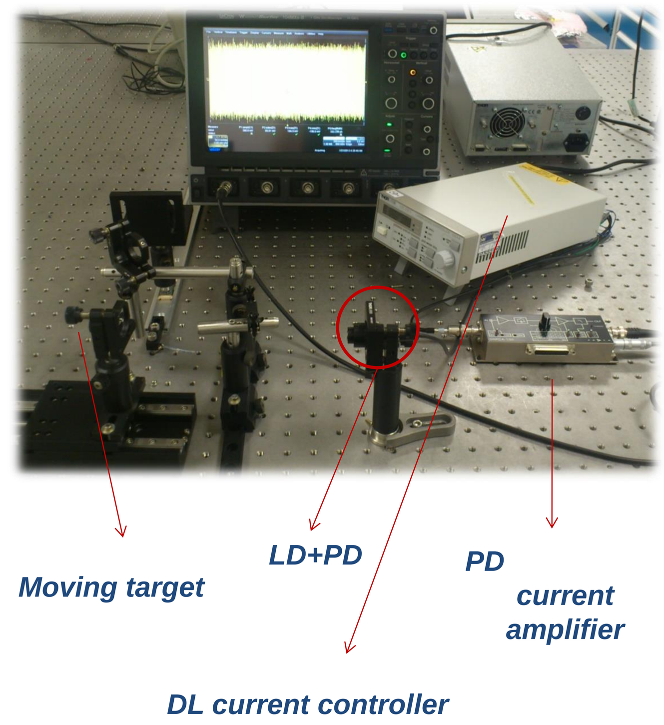


Solution: Self-Mixing Laser Diode

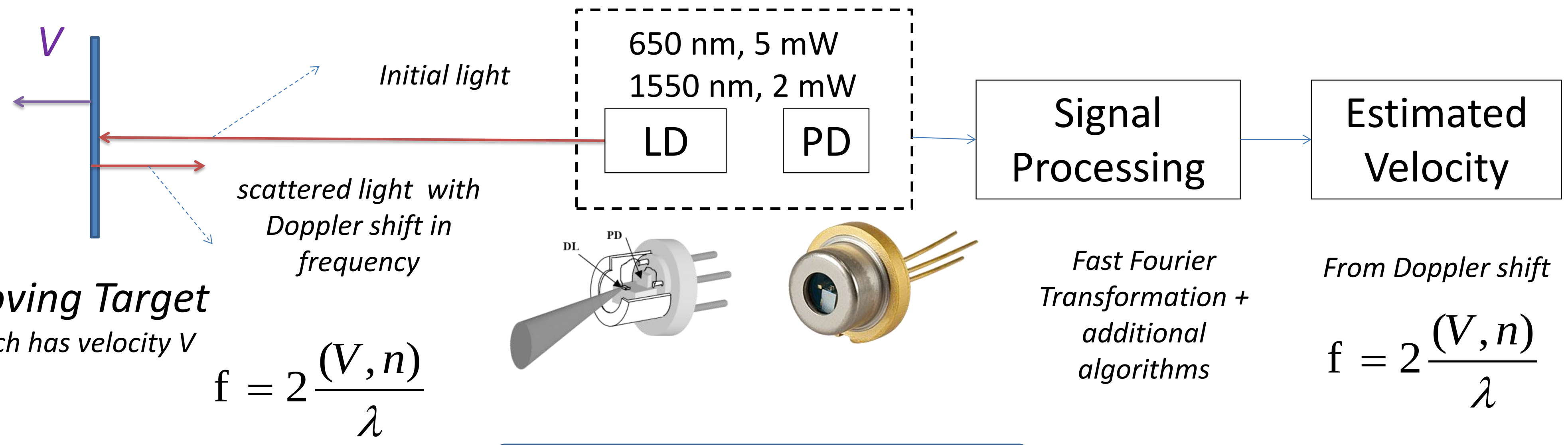


The main advantages of the self-mixing scheme with respect to traditional interferometer are

- *unambiguous measurements,*
- *single interferometric channel,*
- *compactness of the setup,*
- *low cost,*
- *ease of alignment*



Experimental Set-up



$$f = 2\frac{(V,n)}{\lambda}$$

Self-mixing Technique

Small portion of light is reflected from the study object and returned into the laser cavity. It is then mixed with the original wave inside the laser.

Moving Targets

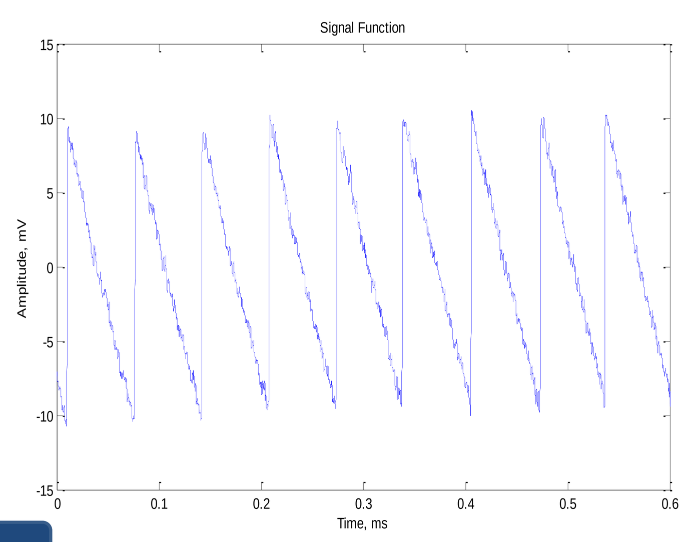
In order to test the SM method, experimental work was divided into several steps, including studies into different target objects:

- mirror (99% reflectivity);
- white paper (scattering);
- fluids;
- gas;

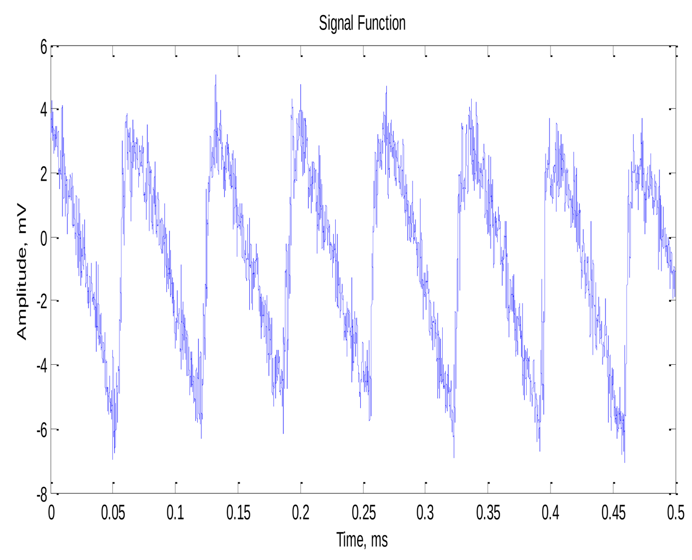
Main results with different targets

Target, reflectivity for 650 nm	Velocity, m/s	Error in the measurement
Mirror, 95%	Up to 0.1	Less than 1%
White paper, 60%	Up to 0.1	Less than 1.5%
White paper on a disc, 60%	Up to 20	Less than 5%

Target: Mirror
(96 % reflectivity on 650 nm)

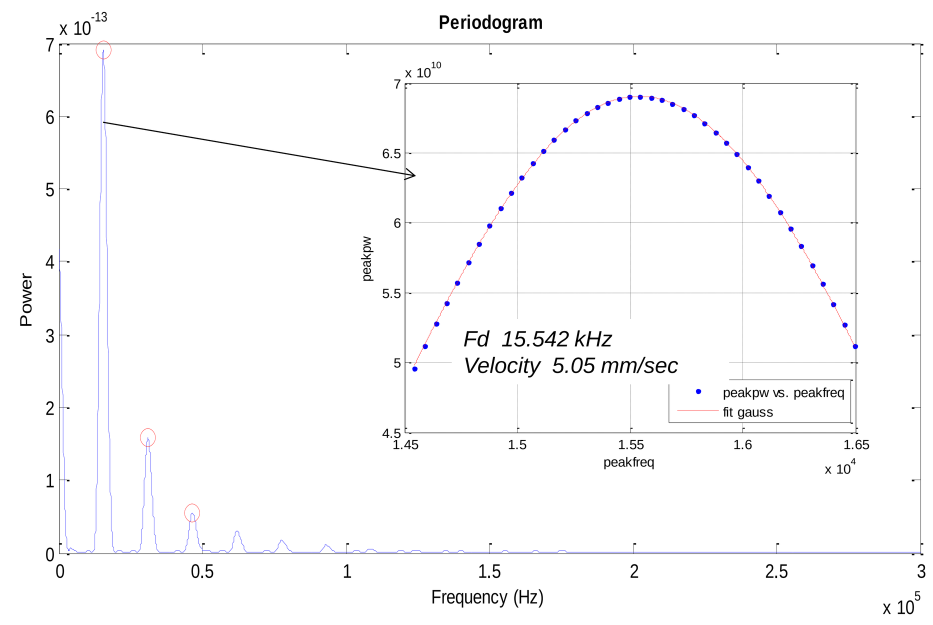


Target: White Paper
(60 % reflectivity on 650 nm)



Signal Processing: FFT

Spectrum calculated by fast Fourier transformation (FFT) Add. algorithms used to suppress speckles and other noise

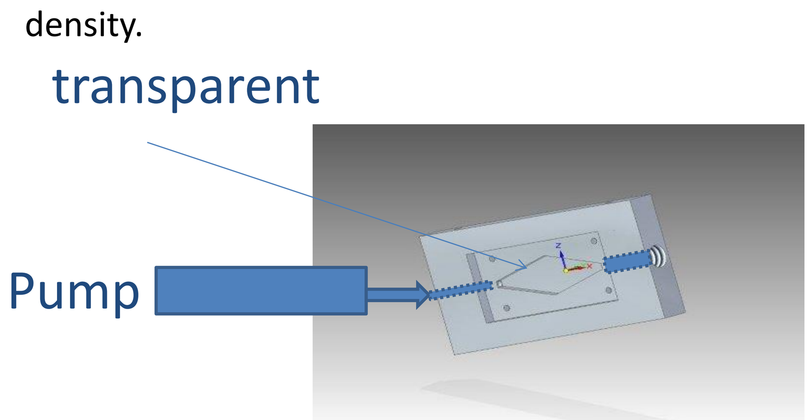


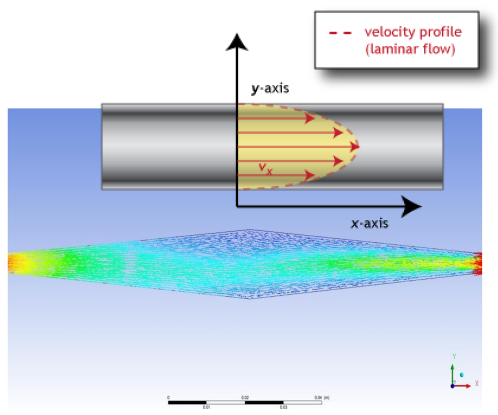
Reference Velocity 5.00 mm/sec (white paper, L=23 cm)

Outlook

Target: Fluid set-up

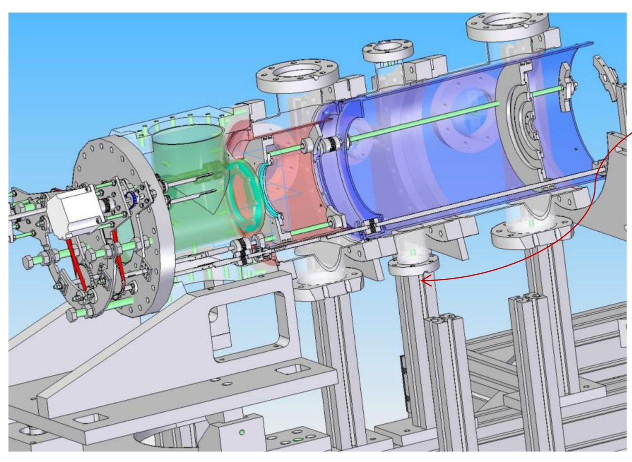
The next step of the experiment is to check the possibility to measure the velocity in the case of scatters of smaller scale. A dedicated set-up for the measurement with a liquid, which allows for defining a distinct velocity distribution so that measurements can be compared about analytical and numerical simulations has been prepared. It is planned to use a mixture of water with milk (5% concentration). This will provide insight into the applicability of the method for targets with lower density.

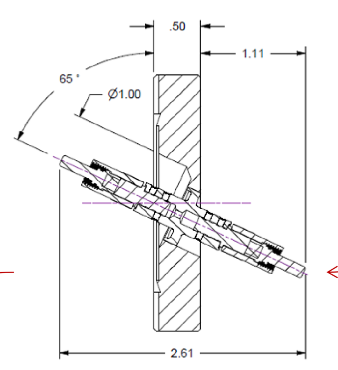




Target: Gas Jet

Difficulties: delivery of the light to the gas jet.

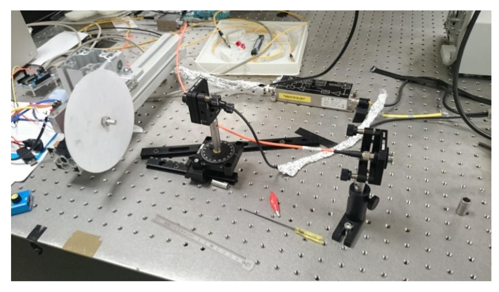




One of the flanges on the set-up could be replaced with the flange that has an optical feedthrough. To have a Doppler shift, the angle between the vector of the velocity and the vector of the laser light should be more than null.

Together with the fiber delivery, the change of the wavelength was decided to be done.

Some experiments based on the 1550 nm laser are to be done.



Solution: it was decided that the easiest way to deliver the laser light would be using fibre. Moreover, the calculation of the level of scattered light on the gas jet showed that the 650 nm won't give enough scattered light for the self-mixing signal.

Conclusion

First results from investigations into a velocimetry based on laser self-mixing for the characterisation of supersonic gas jets as used in advanced beam profile monitors were presented. The preliminary design of such monitor shows good potential for a compact and cost efficient experimental setup. This shall be used for an accurate characterisation of the gas jet, probing simultaneously its density and velocity. Laboratory experiments with different solid targets with varying reflectivity showed the possibility to measure velocities with better than 2% accuracy.

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