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► **To cite this version:**

Sebastián Sierra-Alarcón, Evelio E Ramírez-Miquet, Adam Quotb, Benoit Charlot, Frederik Keizer, et al.. Self-Mixing Interferometry System for in Vitro Retinal Capillary Network Characterization. MNE 2024 | 50th International Micro and Nano Engineering Conference, Sep 2024, Montpellier, France. hal-04785523

**HAL Id: hal-04785523**

**<https://laas.hal.science/hal-04785523v1>**

Submitted on 15 Nov 2024

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# Self-Mixing Interferometry System for in Vitro Retinal Capillary Network Characterization

Sebastián Sierra-Alarcón<sup>a</sup>, Evelio E. Ramírez-Miquet<sup>b</sup>, Adam Quotb<sup>a</sup>, Benoit Charlot<sup>b</sup>, Frederik Keizer<sup>a</sup>, Julien Perchoux<sup>a</sup>

<sup>a</sup> LAAS-CNRS, Université de Toulouse, CNRS, INP, Toulouse, 31000, France

<sup>b</sup> Institut d'Electronique et des Systèmes IES, , Université de Montpellier, CNRS, Montpellier, 34090, France  
e-mail: [julien.perchoux@toulouse-inp.fr](mailto:julien.perchoux@toulouse-inp.fr), [benoit.charlot@umontpellier.fr](mailto:benoit.charlot@umontpellier.fr)

Blood is a complex liquid composed of circulating cells within an extensive network of vessels with irregular topology. To understand the physics of blood flow in these vascular networks, it is essential to create microfluidic replicas of the microcirculation. These replicas allow for the modeling and measurement of local hematocrit [1] and the direct observation of blood dynamics and flow within vessels under a microscope.

To this end, we have developed microfluidic circuits that are more biomimetic than those produced by conventional photolithography techniques, replicating both the network topology and channel shapes. While conventional techniques yield channels with rectangular cross-sections, we employ backside lithography with diffusers [2], which generates rounded channels with heights proportional to their width. Figure 1 shows a model of the retinal vascular network, derived from ocular images.

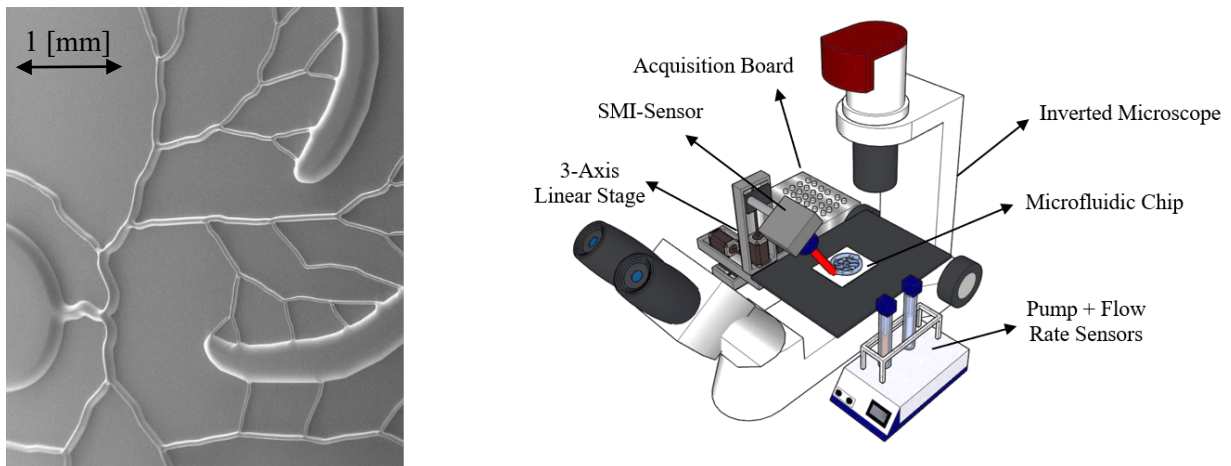
For flow speed measurements, we propose a self-mixing interferometry (SMI) sensing system to scan and measure velocity profiles within microchannels. SMI flowmeters for flow profile characterization (both in vivo and ex vivo) have demonstrated promising results [1-3] in measuring flows of complex fluids, such as a suspension of diffusive fat particles in diluted milk, which closely mimics blood flow. This system enables the analysis of how varying channel cross-sections influence flow rates, velocities, and local hematocrit. The SMI signal is analyzed using the average weighted momentum of its frequency spectrum, which correlates with flow velocity inside the channels, allowing qualitative local velocity measurements [4].

Figure 1 (right) illustrates the assembled SMI imaging system. The system features a 1550 nm laser diode (ThorLabs-L1550P5DFB) with a package-integrated monitoring photodiode. The laser is focused using a 1:1 double lens (AC254-030-C) mounted on a 3-axis linear stage for micrometric scanning. Variations in photodiode current are monitored using a custom transimpedance amplifier for acquisition. The system is integrated with an inverted microscope to observe flow within the microfluidic channels.

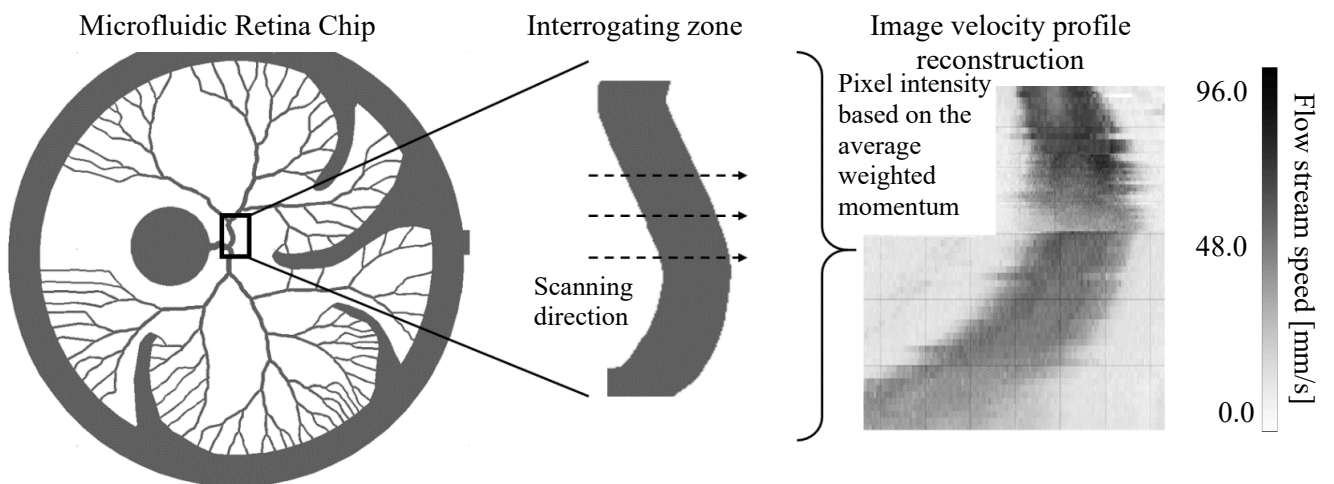
In Figure 2, a velocity map of part of the artificial retinal network is reconstructed via a fully parameterized continuous scan along the chip's x-axis with an adjustable micrometric pixel resolution. The computed image, with 150x170 pixels for the upper portion and 280x94 pixels for the lower portion, demonstrates good resolution of the flowing channel and a strong correlation between channel geometry and the computed weighted moment. Additionally, Figure 3 showcases multiple scans performed on specific channel sections, validating the system's performance in extracting average fluid velocity within microchannels that replicate a vascular network. The system's possible limitations including spot size, channel spacing, channel shape effects, and the angle between scanning direction and flow are addressed. Automated signal processing routines and device orchestration enable flow velocity imaging, offering valuable insights into fluid dynamics in hierarchical networks.

This advancement enhances the study of hemodynamics and hemophysics, supporting investigations of artificial vasculature for organs-on-chips. By mimicking in vivo structures such as retinal vessels, the system provides an accurate and non-invasive method to analyze non-Newtonian flows in capillaries without bulky optical setups or the injection of labeled particles, as required by conventional techniques like  $\mu$ -PIV.

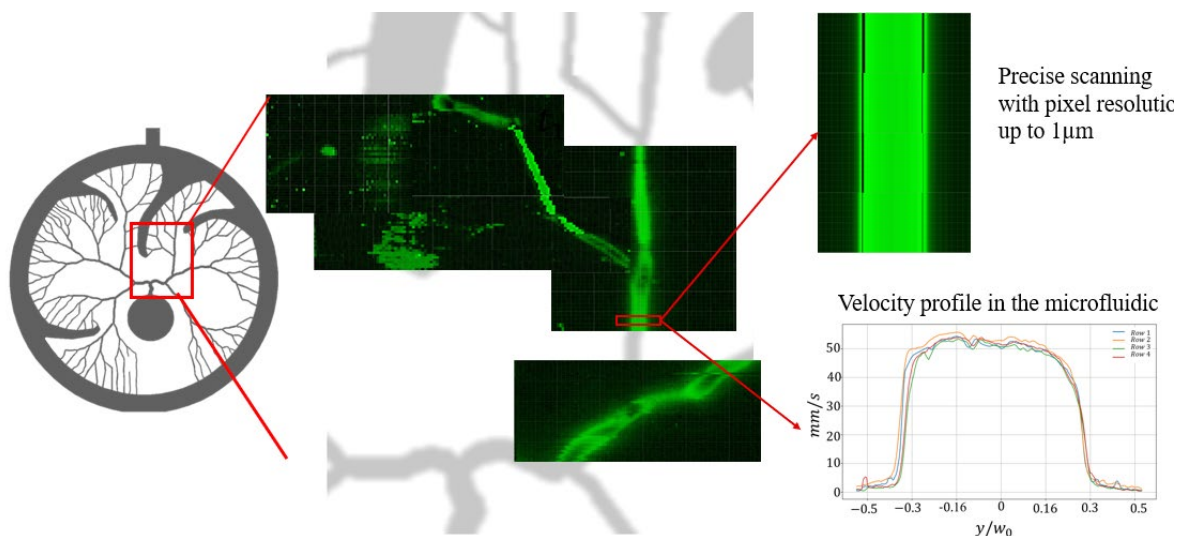
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**Figure 1.** Left: SEM picture of the SU8 on silicon backside lithography mold. Right: Experimental setup assembled for the SMI imaging system.



**Figure 2.** Left: layout of the model retinal vascular network. Right: measurement of the velocity profile scanning based on the average weighted momentum in a specific interrogation zone, where the darkest pixel of the reconstructed image represents a correlation with the higher flow speed in the channel.



**Figure 3.** Results from scans performed on specific channel sections for analyzing flow velocity within the vascular network.