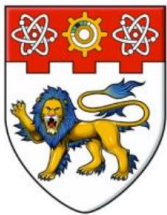


معرفی روش سرعت سنجی تصویری و کاربرد های پردازش تصویر در مطالعه جریان آشفته

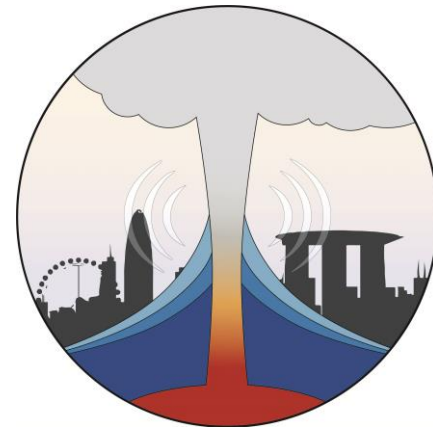
عادل عمادزاده

محقق در مقطع پسا دکترا
دانشکده عمران و محیط زیست
دانشگاه صنعتی نانیانگ
کشور سنگاپور

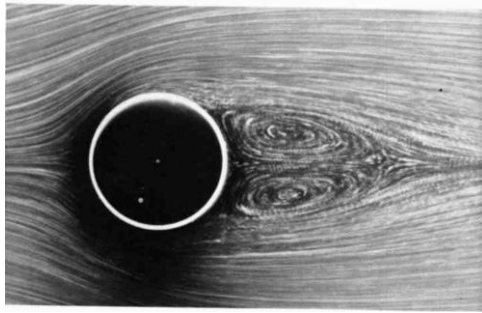
Email: aemadzadeh@ntu.edu.sg
Website: adelemadzadeh.com



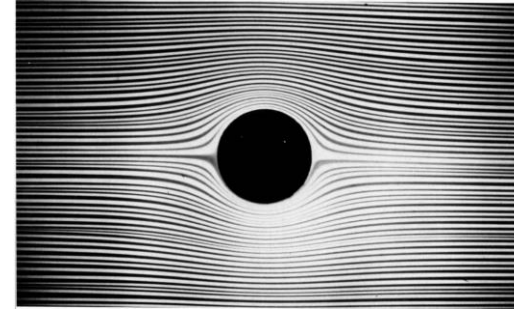
NANYANG
TECHNOLOGICAL
UNIVERSITY



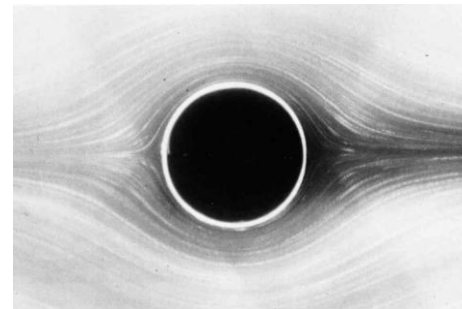
تاریخچه تجسم حرکت سیال



تجسم حرکت سیال با جوهر حول استوانه
 $Re=26$
Photographed by Taneda*



تجسم حرکت سیال با جوهر اطراف
استوانه
Photographed by D. H Peregrine *



تجسم حرکت سیال با جوهر حول استوانه
 $Re=0.16$
Photographed by Taneda*



نقاشی لئوناردو داوینچی از
گردابه های جریان آشفته

https://en.wikipedia.org/wiki/Vortex_stretching

* Van Dyke, M., and Van Dyke, M. (1982). "An album of fluid motion."

از عکس آنالوگ به دیجیتال



عکاسی دیجیتال

عکاسی آنالوگ

دوربین سریع
محصول کمپانی فوترون

<https://photron.com>

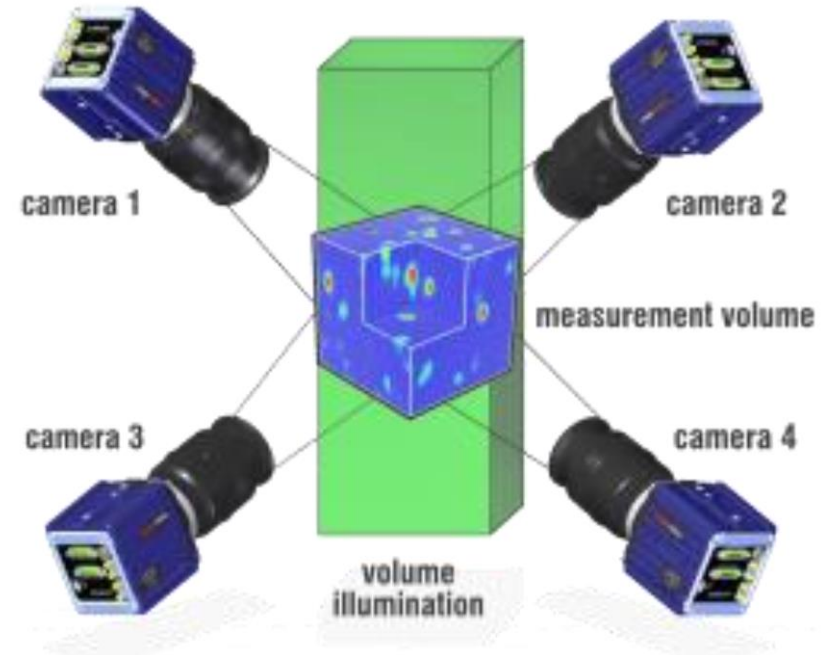
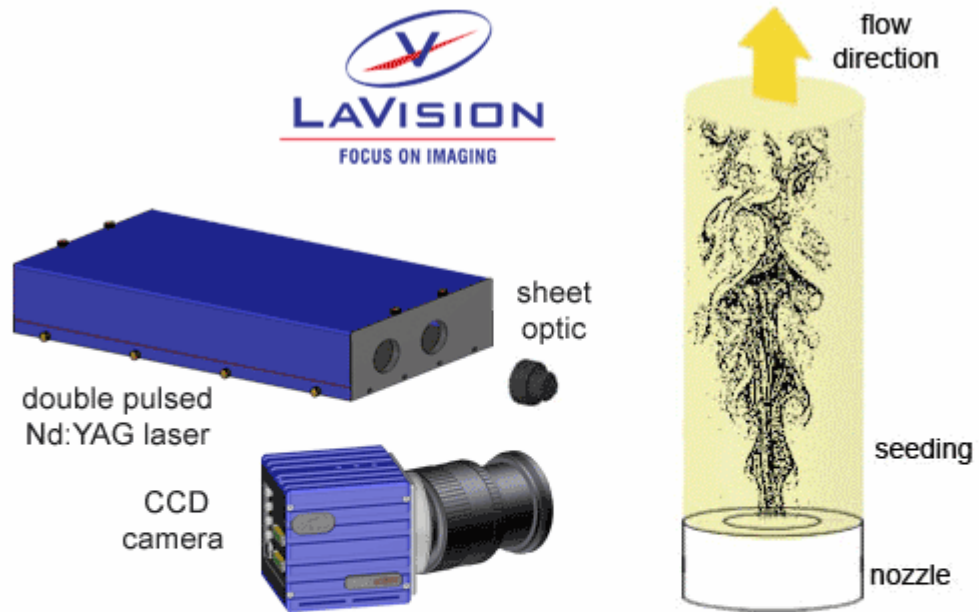
اولین دوربین دیجیتال دنیا
محصول کمپانی کداک

By Kodak and Steve Sasson
<https://petapixel.com/>

Courtesy of George Hodan
<https://www.publicdomainpictures.net/en/brows-e-author.php?a=8245>

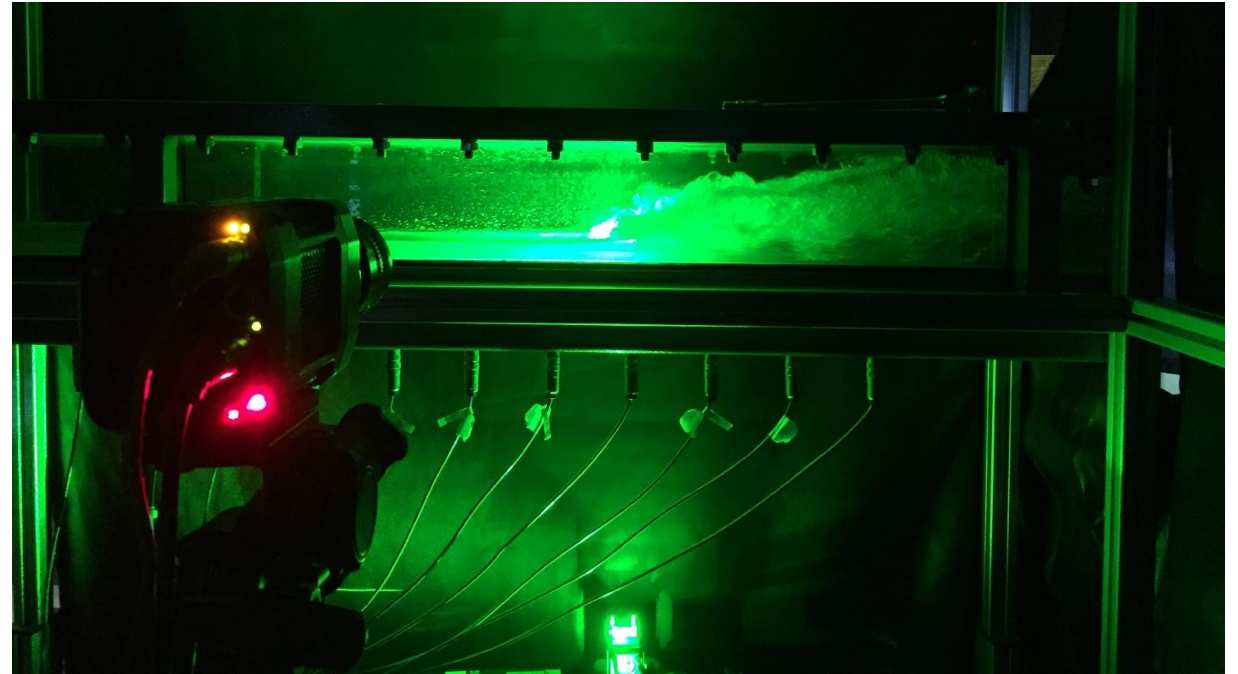
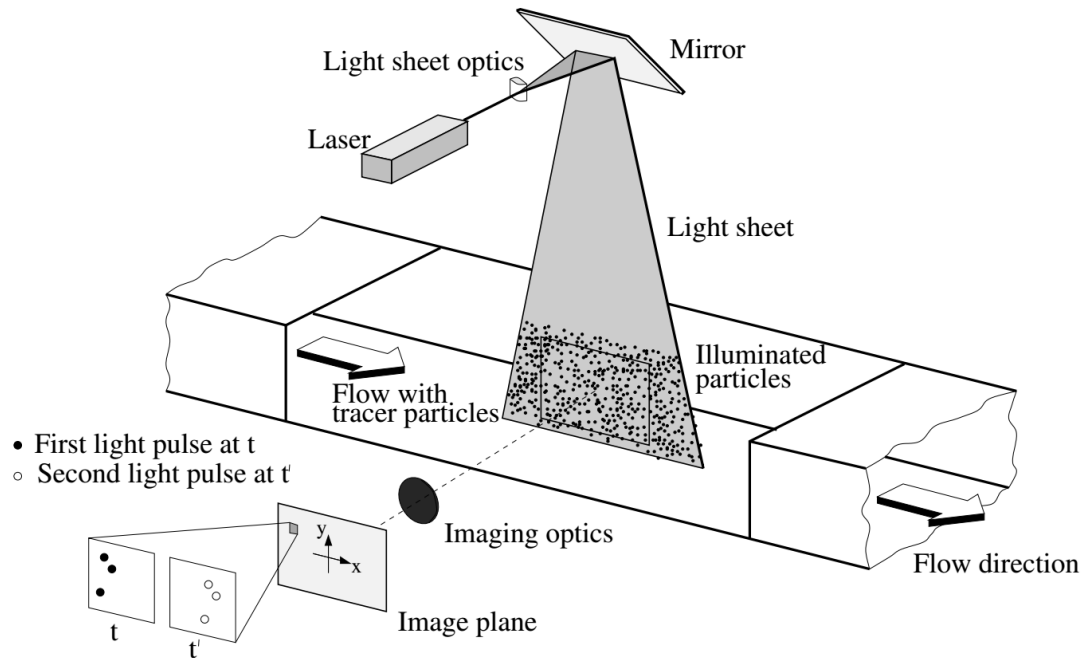
روش سرعت سنجی تصویری

Particle Image velocimetry



Particle Image Velocimetry
<https://www.lavision.de>

سرعت سنجی تصویری



*شمای دستگاه سرعت سنج تصویری

استفاده از دستگاه سرعت سنج تصویری دو بعدی برای اندازه گیری سرعت در پرش هیدرولیکی

*Raffel, M., C. E. Willert, and J. Kompenhans (2013), Particle image velocimetry: a practical guide, Springer.

*Emadzadeh, A., and Y. M. Chiew (2017), Bubble dynamics and PIV measurements in a hydraulic jump, in *Proceeding of 37th IAHR World Congress, Kuala Lumpur, Malaysia.*, edited, pp. 1313-1319.

دوربین

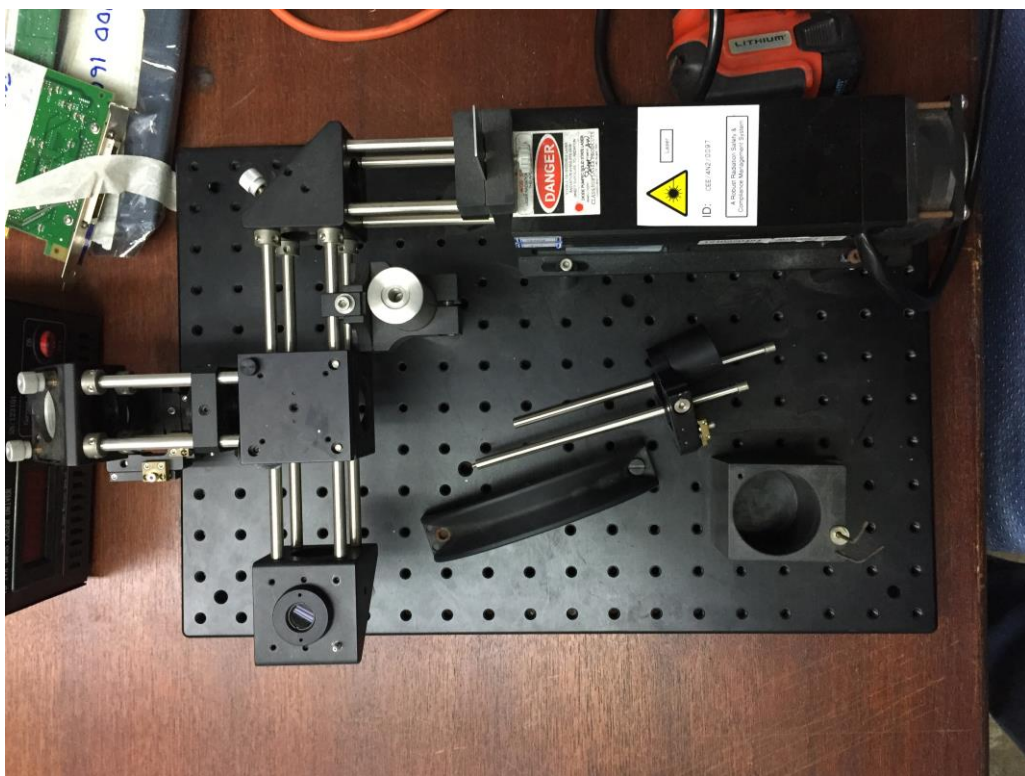


Miro M311
3,200 fps at 1280 x 800
12 GB RAM



Miro M120
6,600 fps at 2048 x 1920
12,500 fps at 1920 x 1080
72, 144, or 288GB RAM

لیزر



دید از بالا



دید از جانب

ذرات رهگیر در مایعات

Polyamide particles

Polyamide particles, 55 μm , 1.2g/cm³

Polyamide particles, 100 μm , 1.1 g/cm³

Polyamide particles HQ, 20 μm , 1.03g/cm³

Polyamide particles HQ, 60 μm , 1.03g/cm³

Fluorescent particles

Melamine resin density 1.51 g/cm³

Polysterene (PS) density 1.05 g/cm³,

PMMA density 1.19 g/cm³,

Glass hollow spheres (Silver coated)

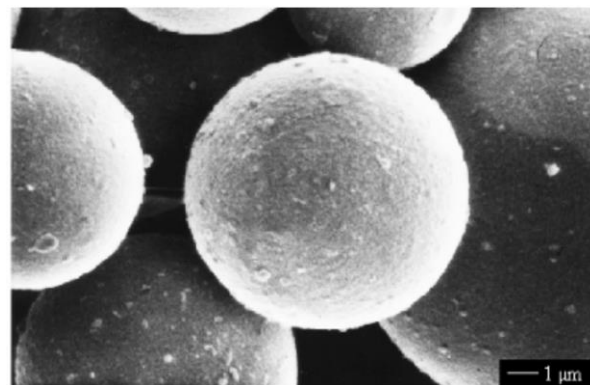
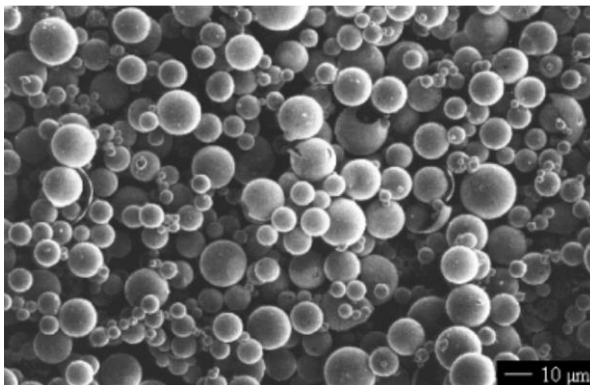
Glass hollow spheres, 9-13 μm , 1.1g/cm³

Glass hollow spheres SC, 10 μm , 1.7 g/cm³

Ceramic hollow spheres (SC), 100 μm , 1.1 g/cm³

PLIOLITE VTAC-H

1.01 g/cm³, 1000 μm , (1mm)



Micrographs of silver coated hollow glass spheres: $\times 500$ and $\times 5000$.

Software

Commercial

- Dantec Dynamics (Denmark)
- TSI Incorporated (United States of America)
- LaVision (Germany)
- PIVtech (Germany)
- MicroVec (China)

OpenSource

- PIVLab (Matlab)
<http://pivlab.blogspot.no/>
- MatPIV (Matlab)
<https://www.mn.uio.no/math/english/people/aca/jks/matpiv/>
- JPIV
<http://www.jpiv.vennemann-online.de/index.html>
- OpenPIV (Matlab, Python, C++)
<http://www.openpiv.net/>
<http://www.damtp.cam.ac.uk/lab/digiflow/>

جریان حول ذرات کروی در حال سقوط



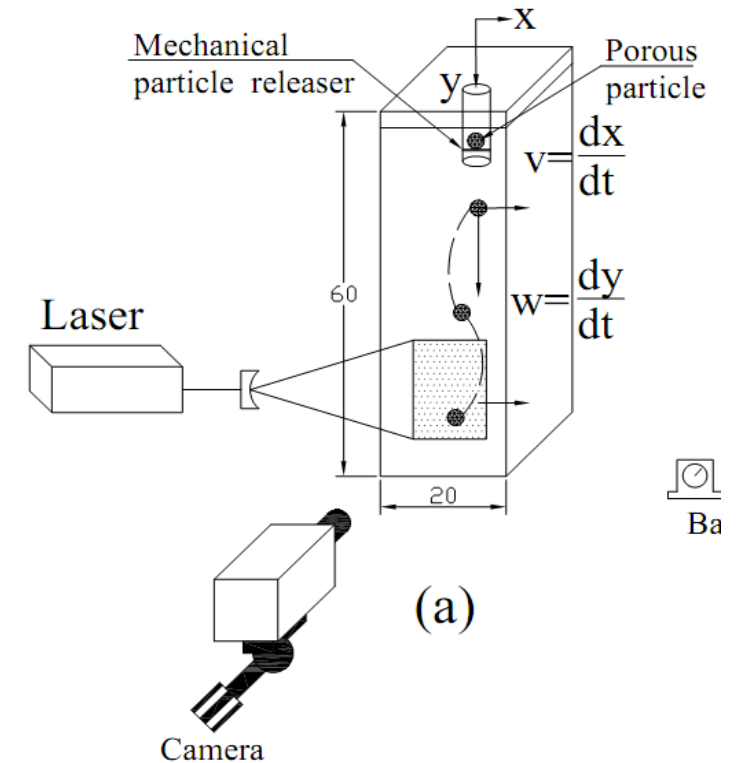
Porous particles with $D = 14$ mm prepared with Alloy 1-4

Table 1. Properties of wire material

	Alloy 1	Alloy 2	Alloy 3	Alloy 4
ρ_s (g/cm ³)	10.812	9.178	7.779	6.718
D (mm)	14,18	14,18	14,18	14
ε	0.6-0.95	0.6-0.95	0.6-0.95	0.6-0.96

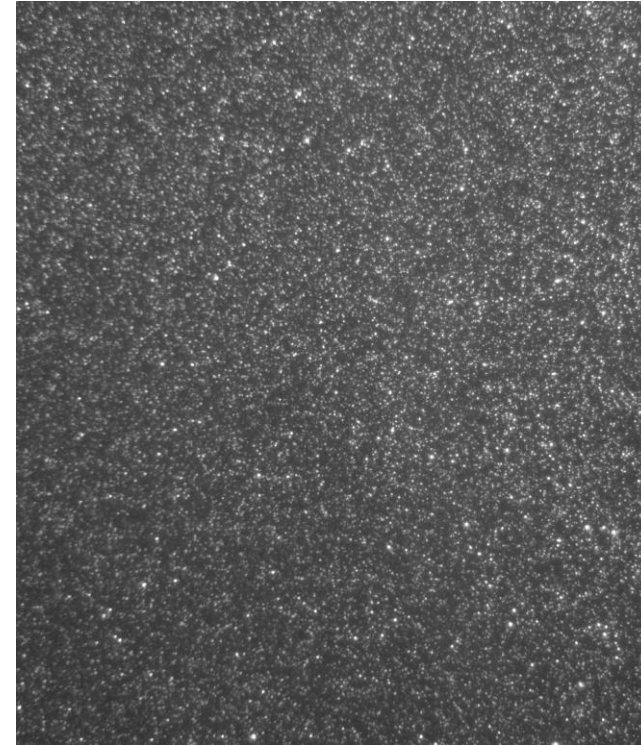
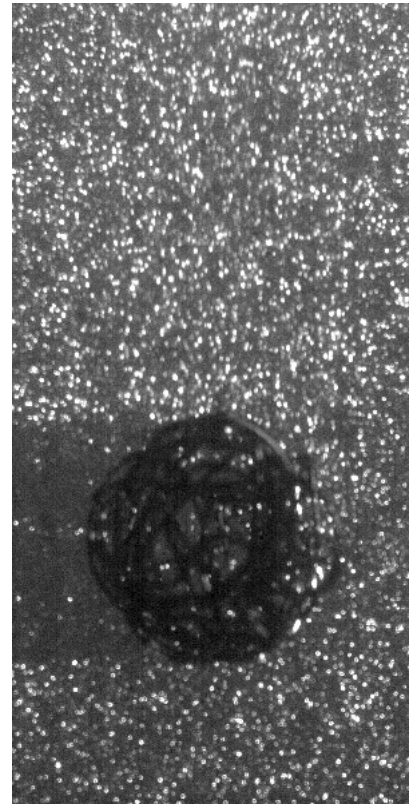
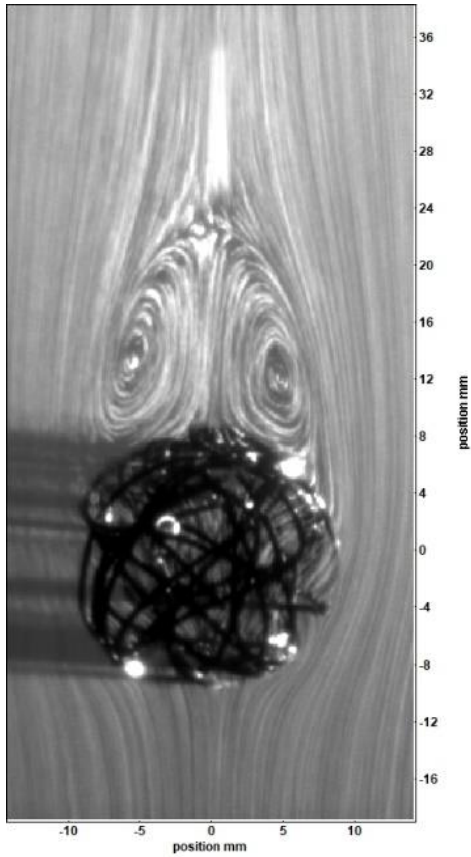
Table 2. Viscosities and densities of fluid mediums used for settling experiments

Fluid Medium	Glycerol mass concentration C_m (%)	Density ρ_l (g/cm ³)	Dynamic Viscosity μ_l (g/cm.s)
Glycerol	100	1.258	6.482
Mixture 1	95.8	1.246	2.536
Mixture 2	87.1	1.224	0.763
Mixture 3	68.4	1.175	0.128
Mixture 4	45.2	1.114	0.0337
Water	0	0.996	0.00853



شماتیک آزمایش

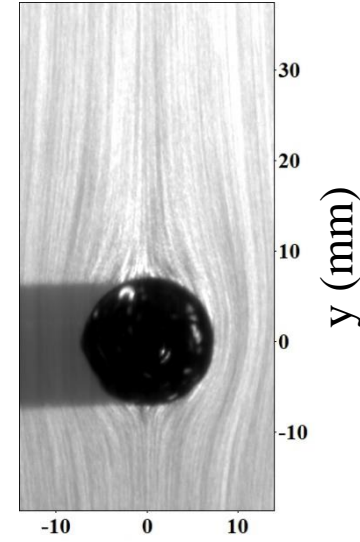
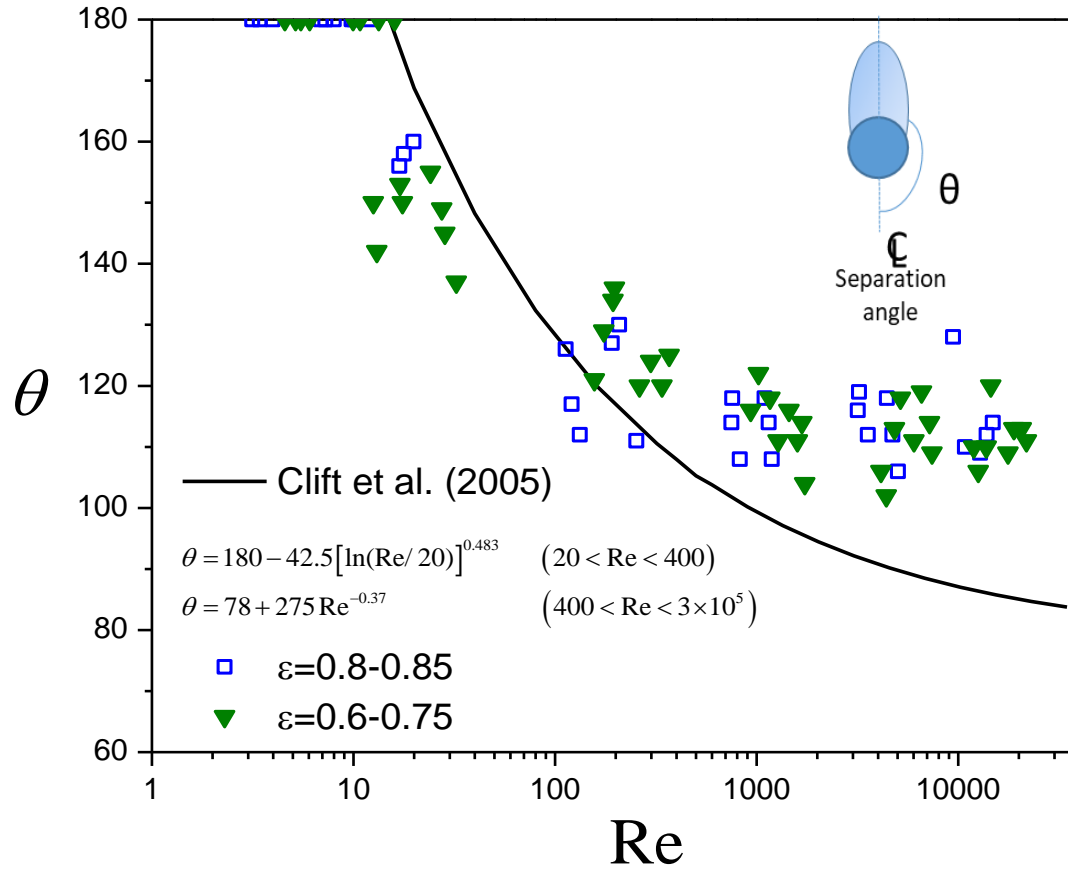
جریان حول ذرات کروی در حال سقوط



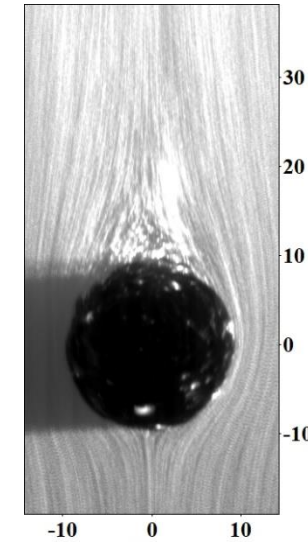
تصویر پردازش شده

تصویر اصلی

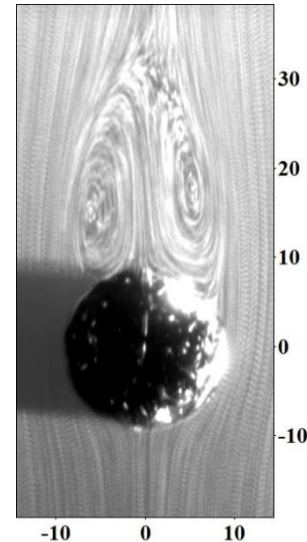
تجسم حرکت سیال



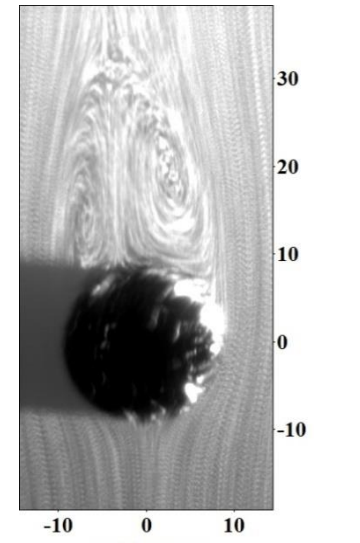
x (mm)
 $\text{Re}=10 \ \epsilon=0.83$



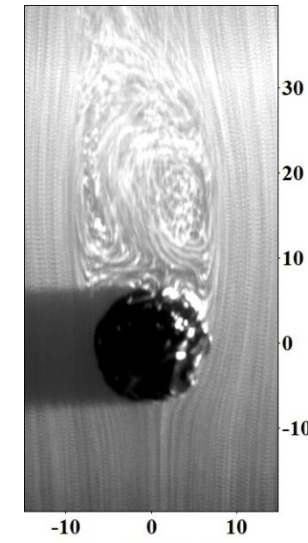
$\text{Re}=12.5 \ \epsilon=0.65$



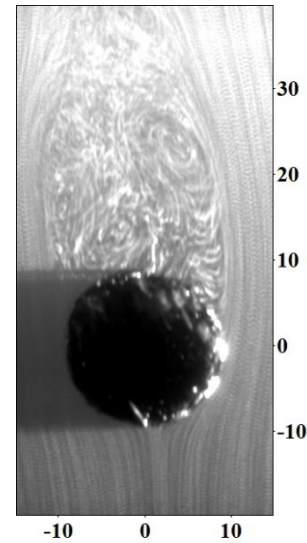
$\text{Re}=262, \ \epsilon = 0.75$



$\text{Re}=298, \ \epsilon = 0.7$

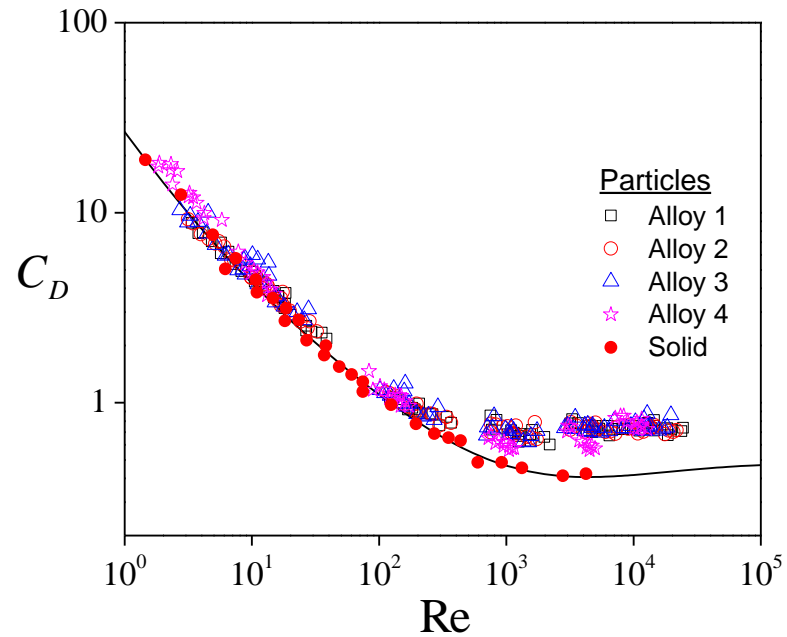


$\text{Re}=757, \ \epsilon = 0.83$

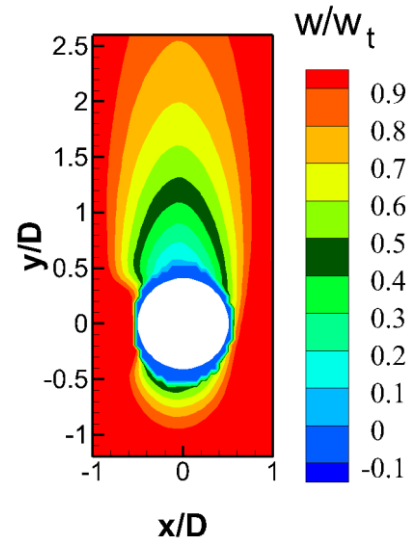


$\text{Re}=12,835 \ \epsilon=0.85$

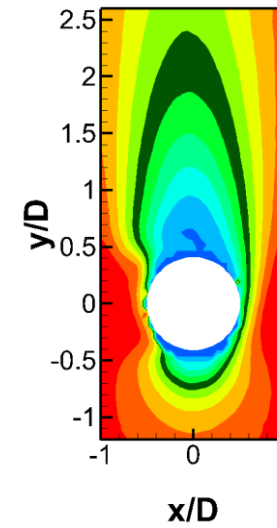
Normalized time-averaged vertical velocity field, w/w_t



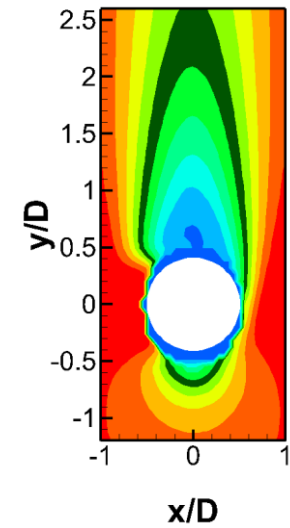
Comparison the C_D versus Re relation for solid and porous spherical particles.



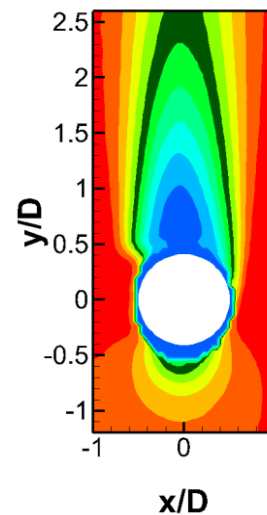
$\epsilon=0.85, Re=3.2$



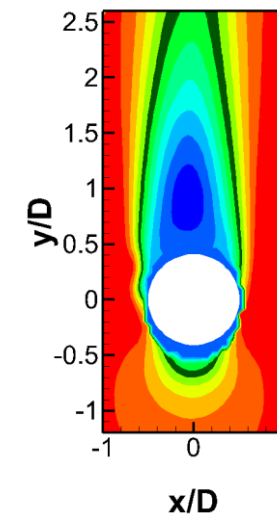
$\epsilon=0.6, Re=6.1$



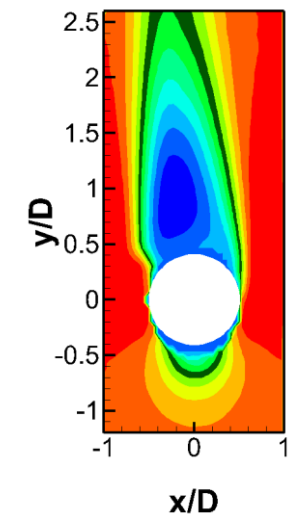
$\epsilon=0, Re=11$



$\epsilon=0.85, Re=113$

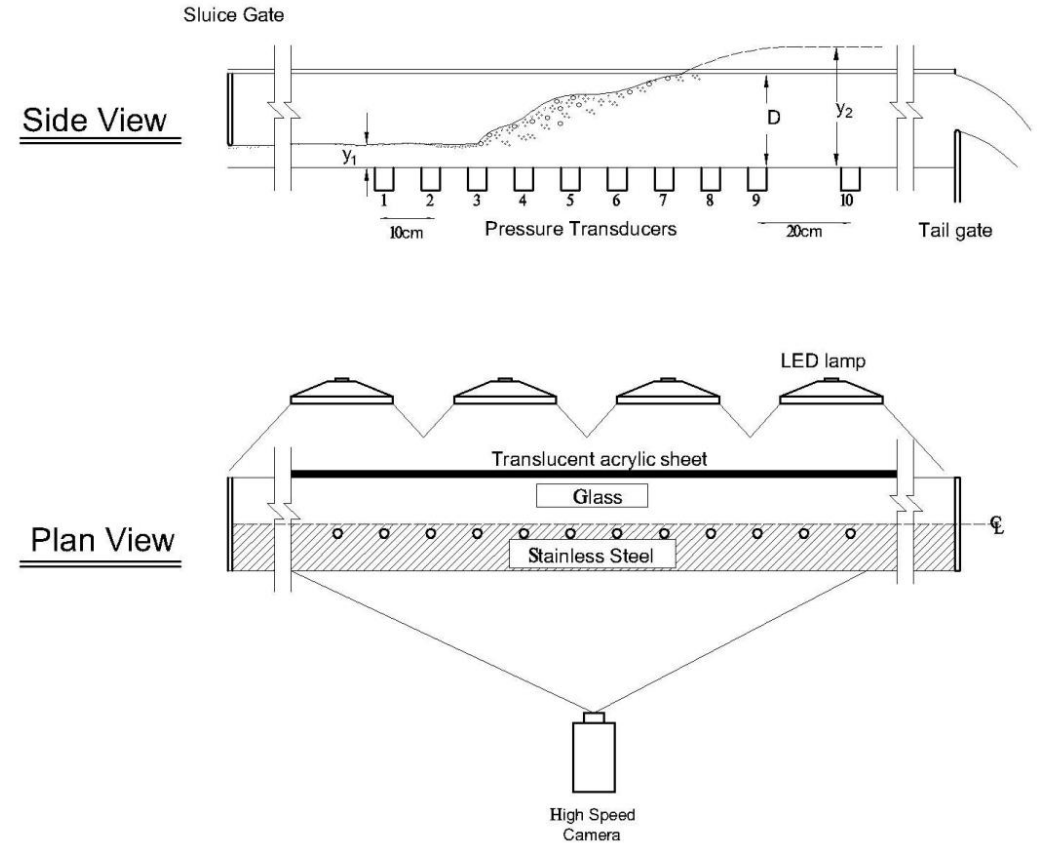
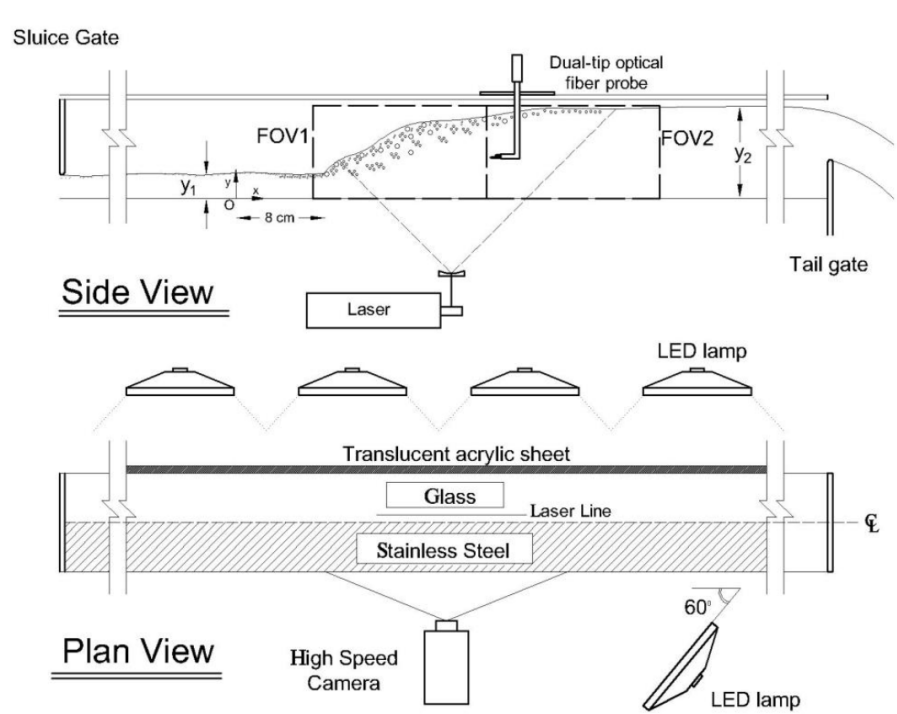


$\epsilon=0.6, Re=197$



$\epsilon=0, Re=351$

پیش هیدرولیکی



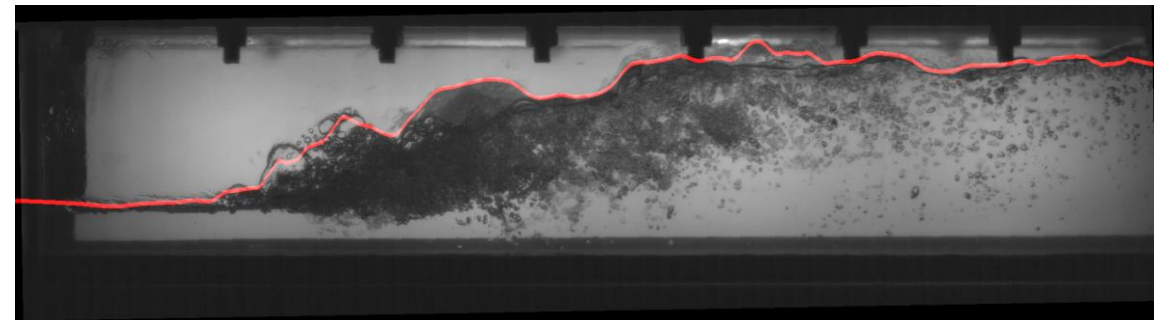
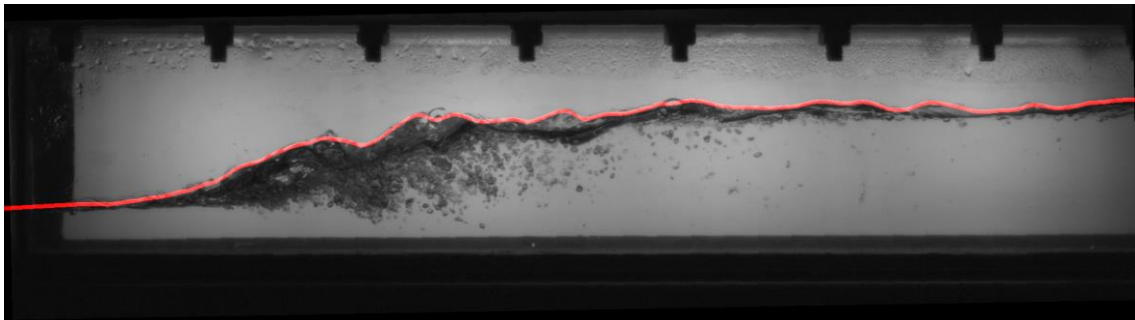
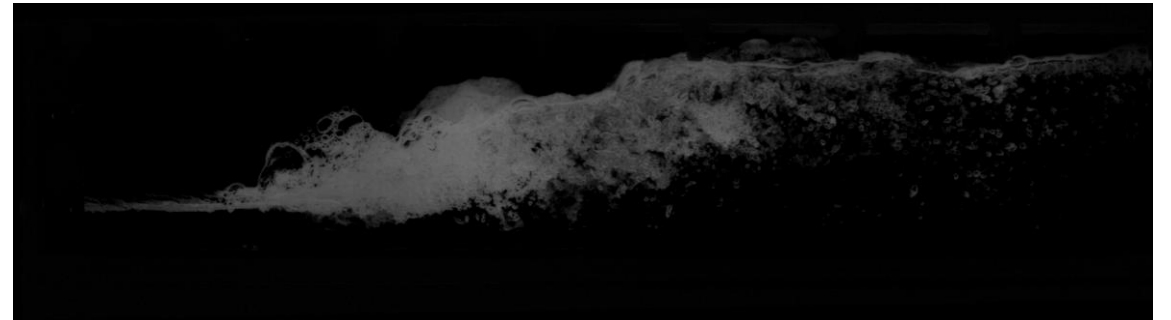
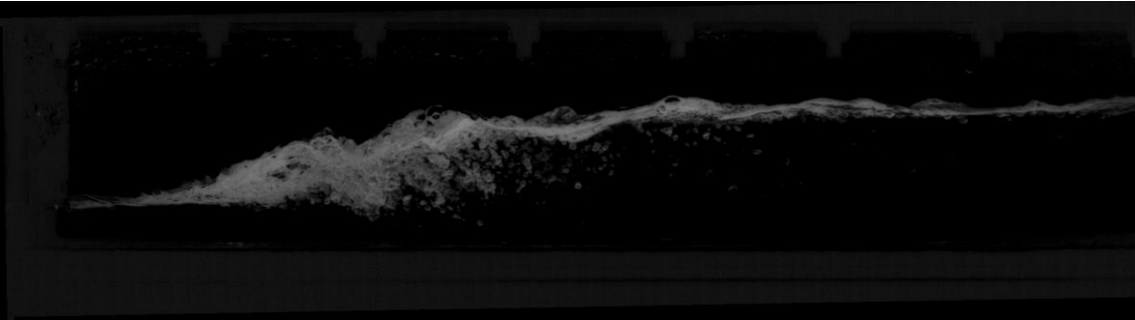
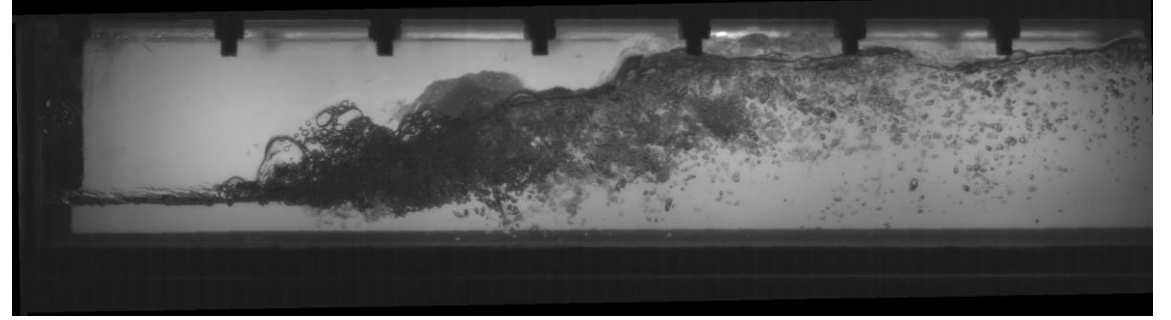
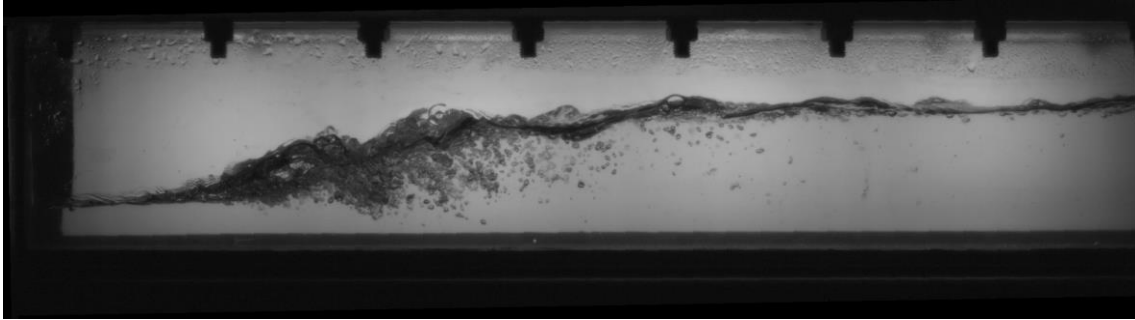
- Chiew, Y. M., and A. Emadzadeh (2017), Experimental investigation of free surface dynamics and pressure fluctuations in a closed-conduit hydraulic jump, in *Proceeding of 37th IAHR World Congress, Kuala Lumpur, Malaysia.*, edited, pp. 1271-1279.
- Emadzadeh, A., and Y. M. Chiew (2017), Bubble dynamics and PIV measurements in a hydraulic jump, in *Proceeding of 37th IAHR World Congress, Kuala Lumpur, Malaysia.*, edited, pp. 1313-1319.

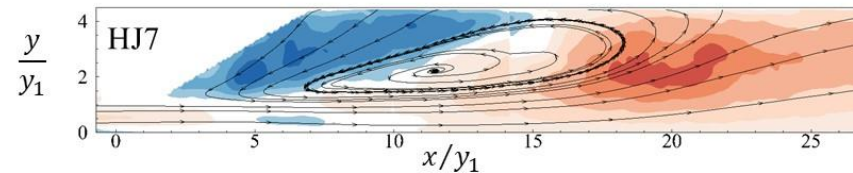
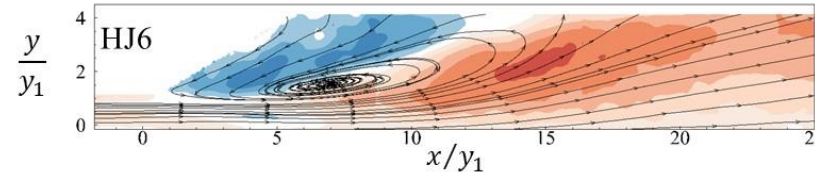
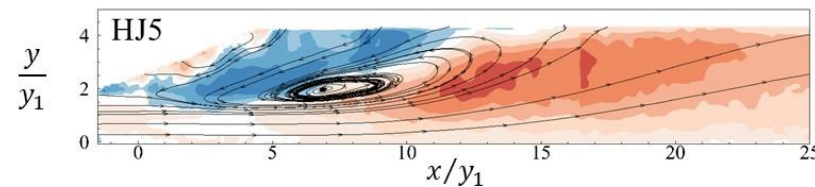
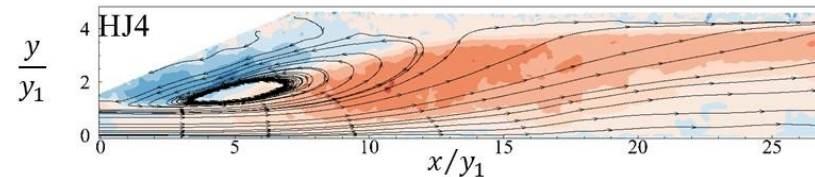
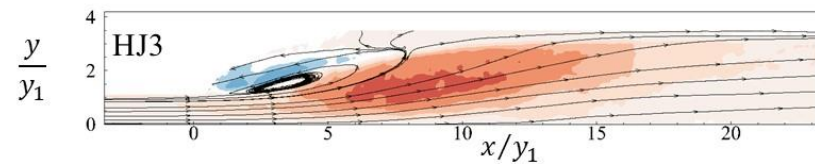
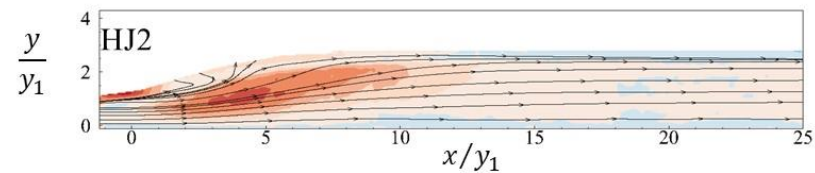
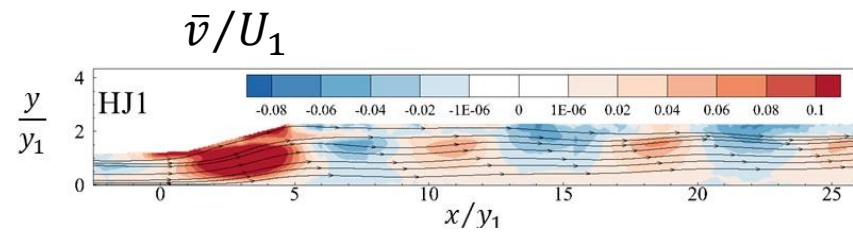
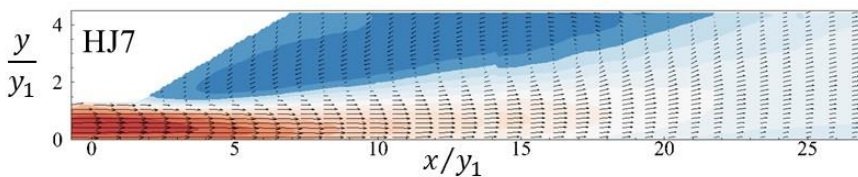
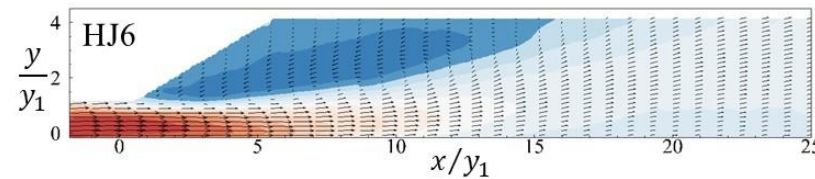
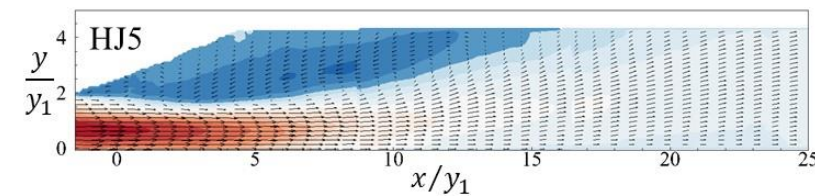
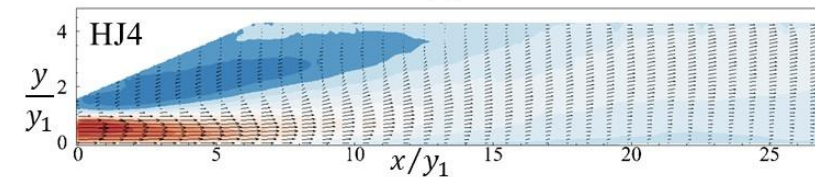
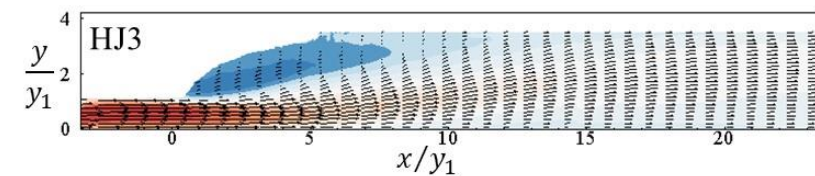
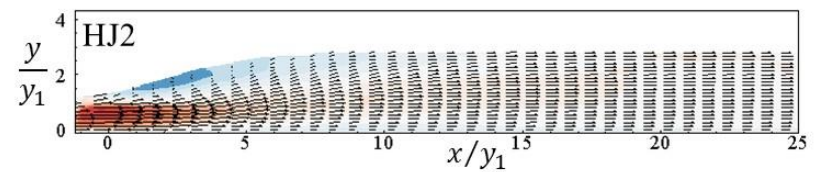
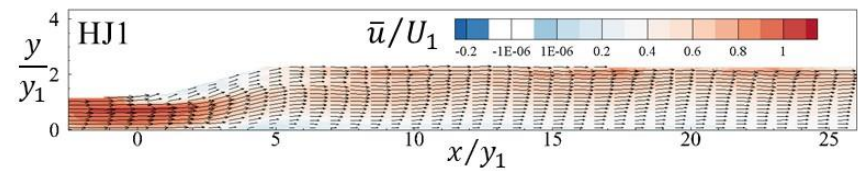
استفاده از نور سفید



GSVITEC ▶

اندازه گیری نوسانات سطح آب





کاربرد روش سرعت سنجی تصویری در علوم زمین



Strombolian eruption

Photo credit: Tom Pfeiffer

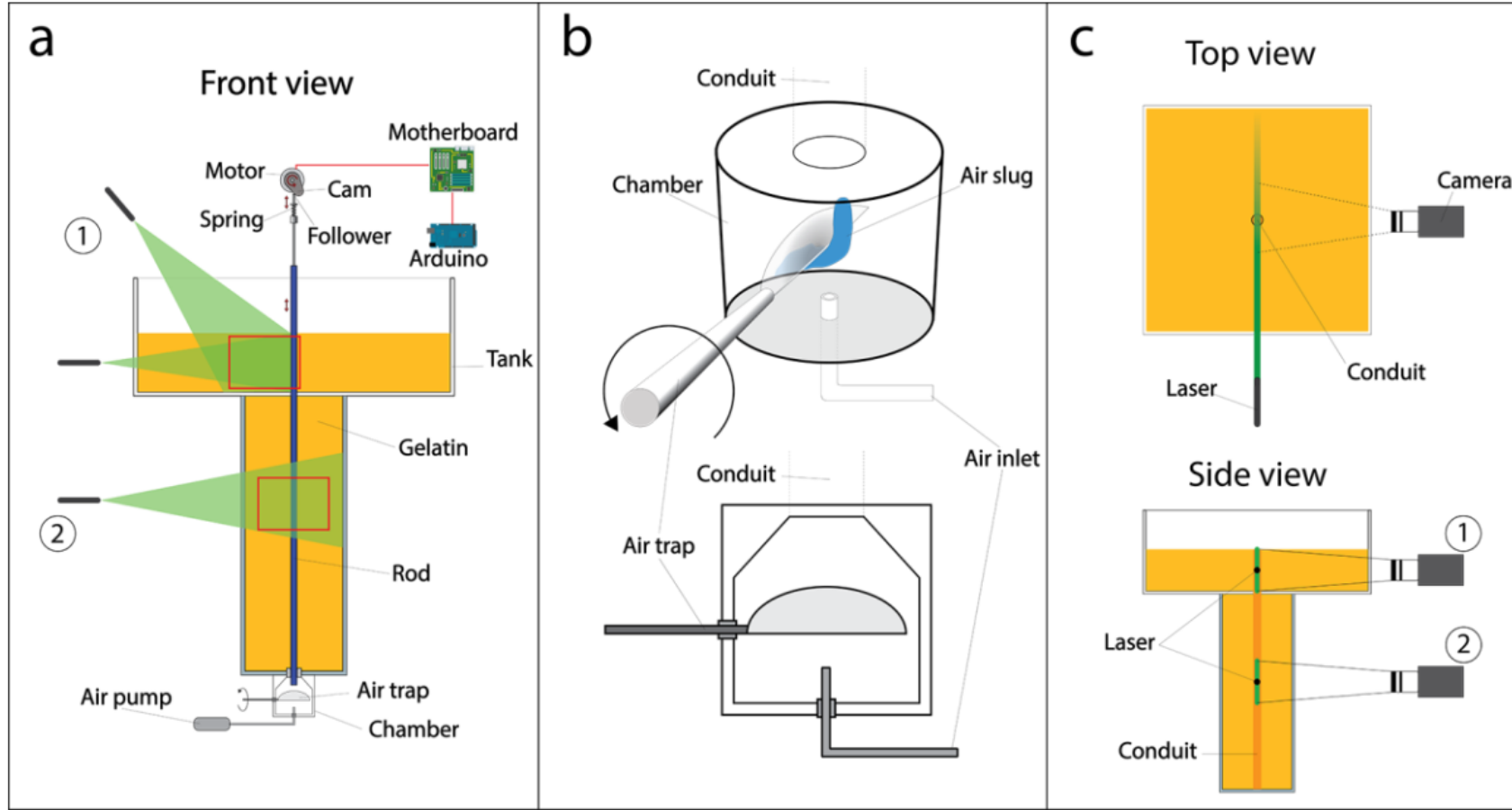


Dyke eruption

(Bárðarbunga in Iceland, 2014)

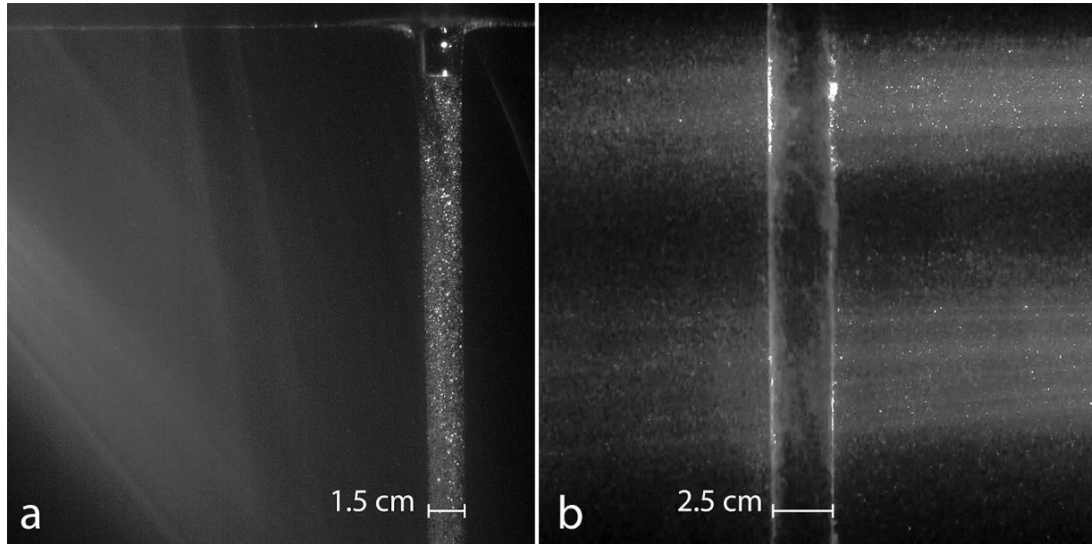
Photo credit: Einar Gudmann

کاربرد روش سرعت سنجی تصویری در علوم زمین

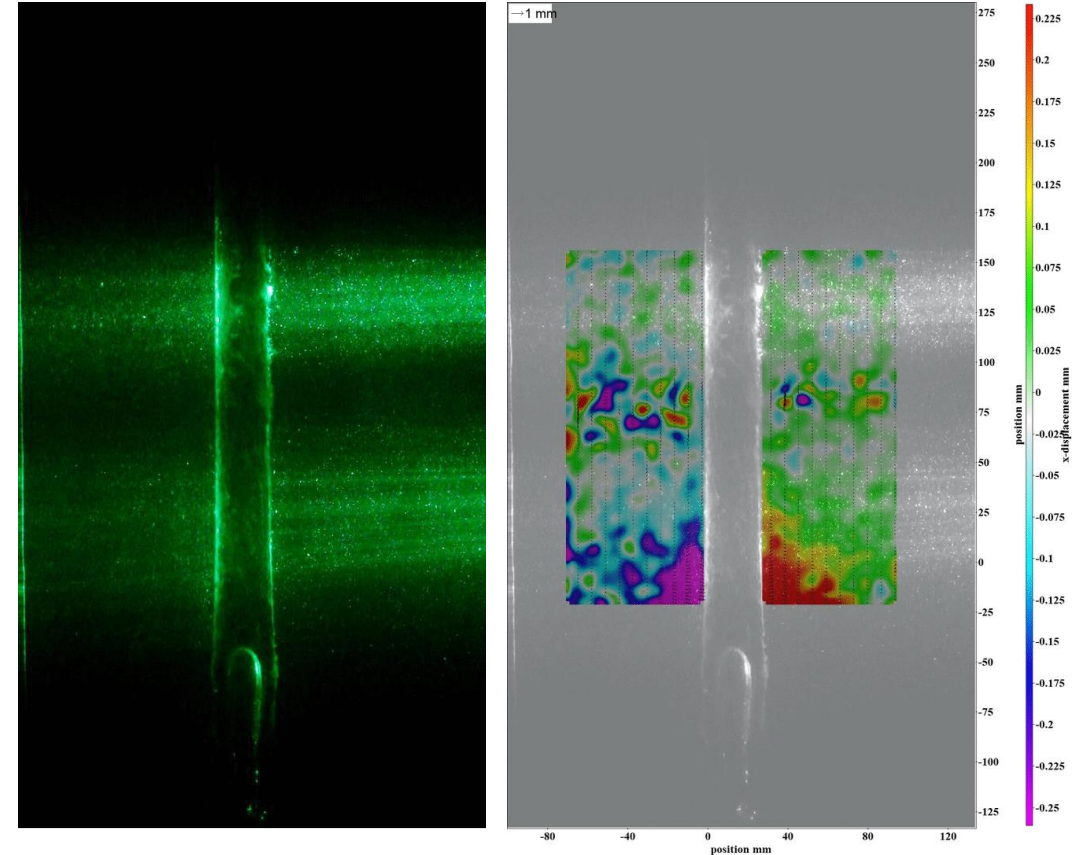


شماتیک آزمایش

کاربرد روش سرعت سنجی تصویری در علوم زمین



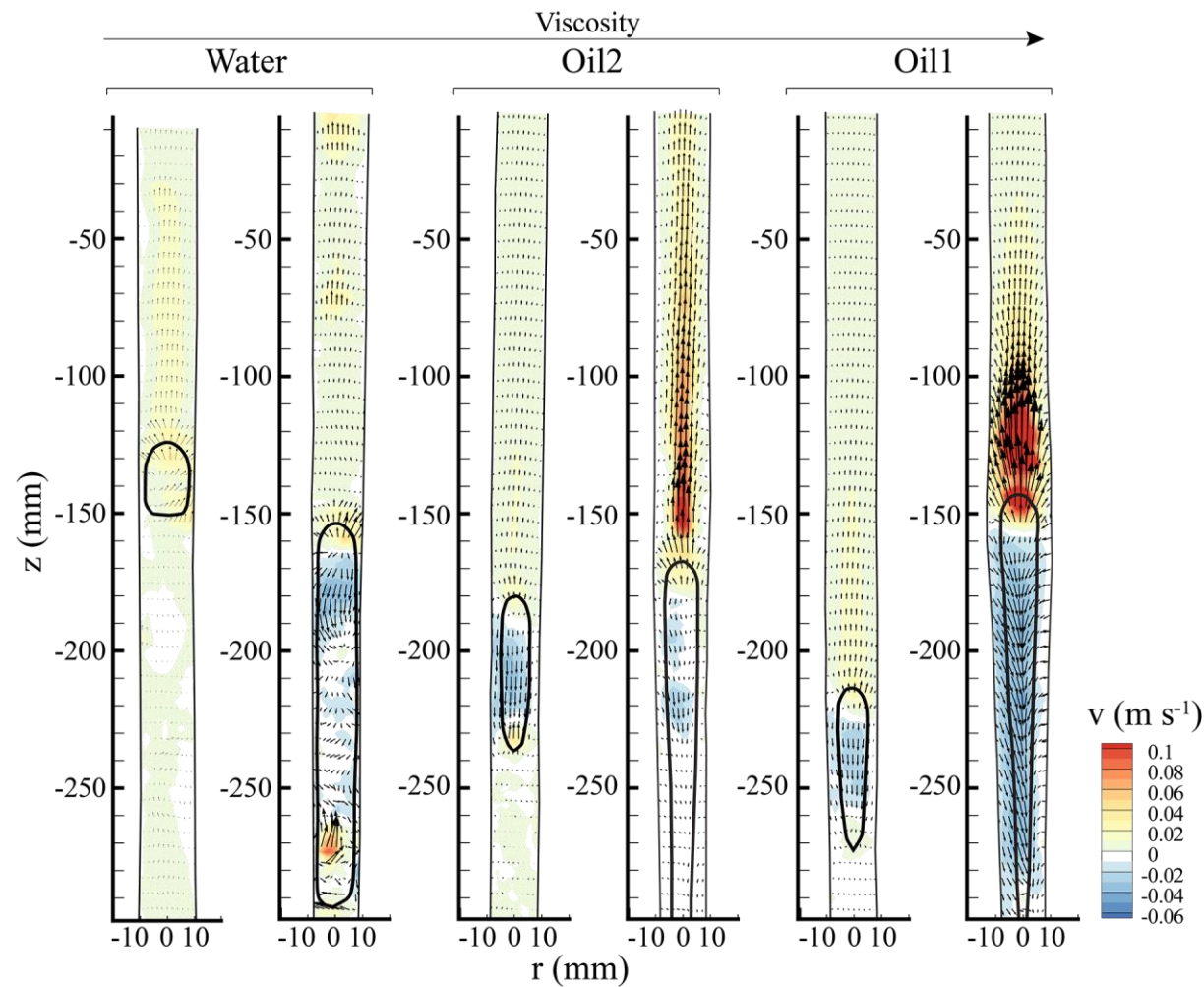
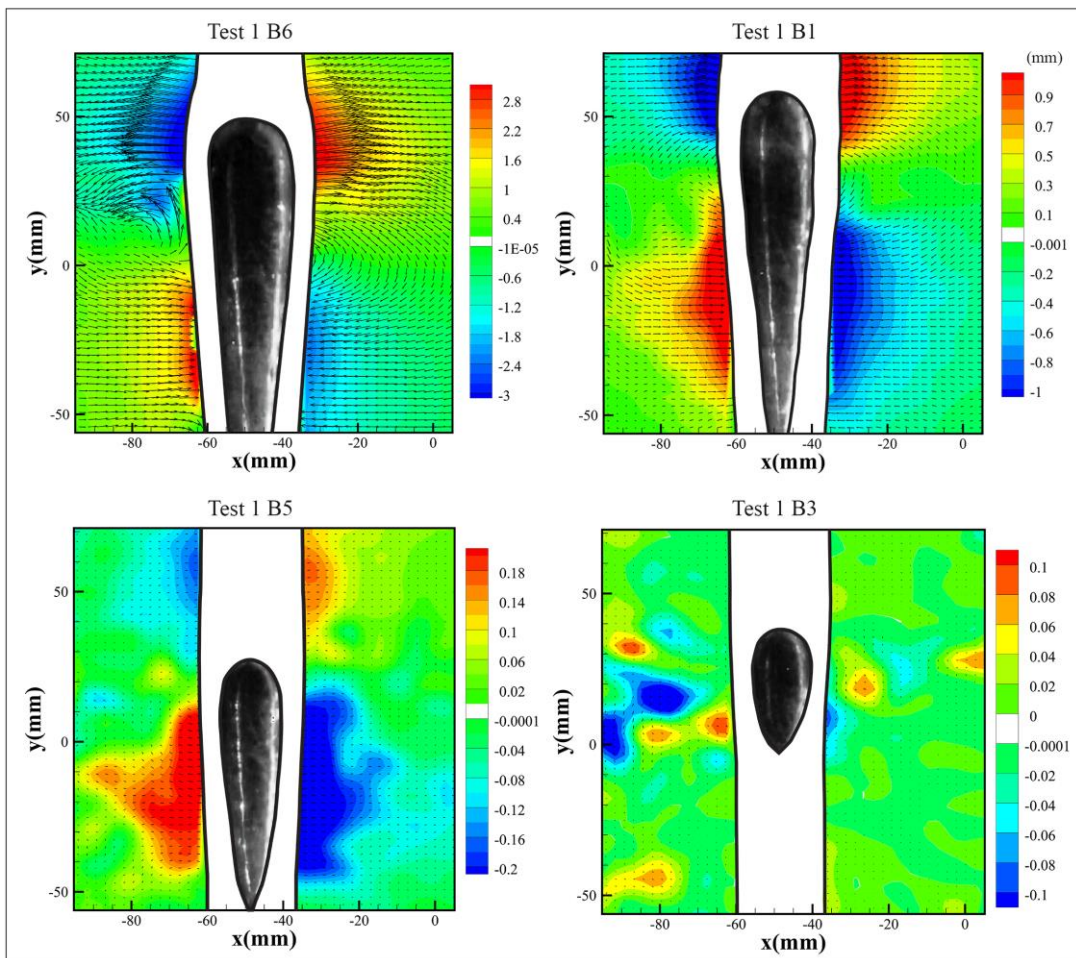
تصویر اصلی



Deformations in the elastic conduit
Measured by Particle Image Velocimetry (PIV)*

Manta, F., **A. Emadzadeh**, and B. Taisne (2019), New insight into a volcanic system: Analogue investigation of bubble-driven deformation in an elastic conduit, *Journal of Geophysical Research: Solid Earth*(124), doi: 10.1029/2019JB017665.

کاربرد روش سرعت سنجی تصویری در علوم زمین

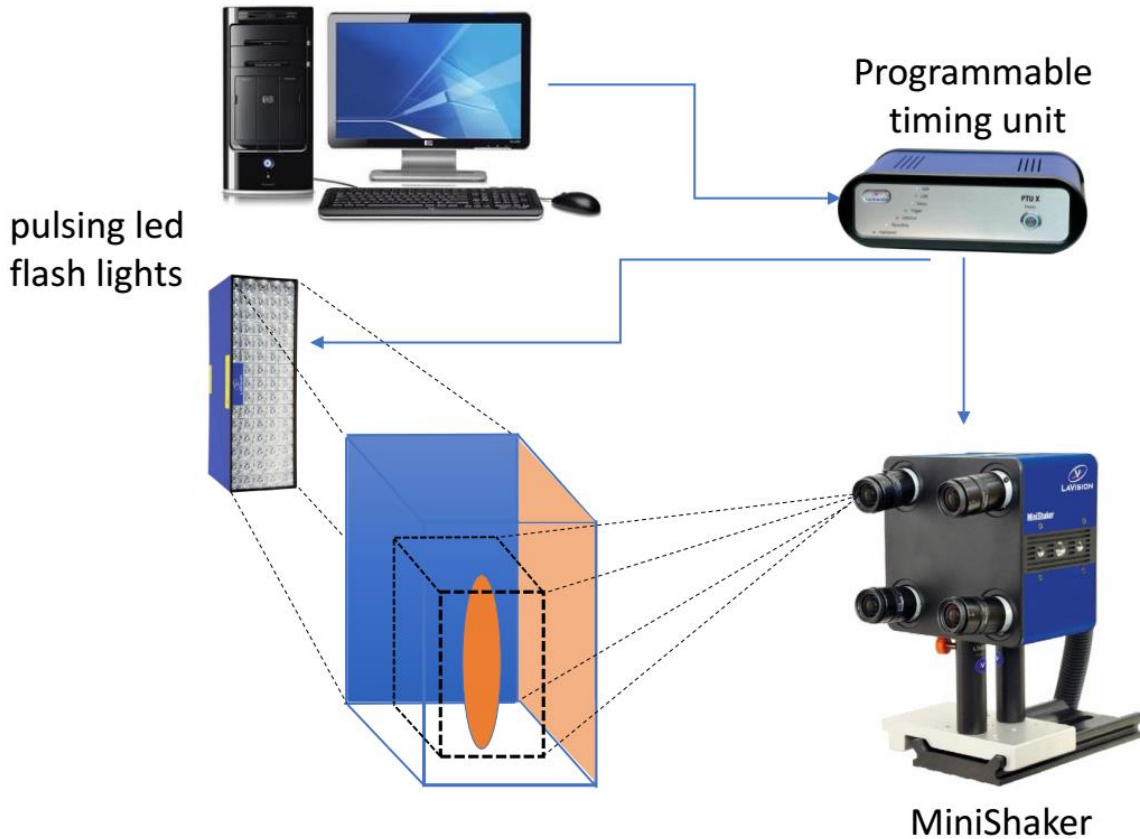


تغییر شکل مجرای آتشفشان در اثر حرکت حباب گاز

توزیع سرعت درون مجرای آتشفشان

Minishaker (LaVision)

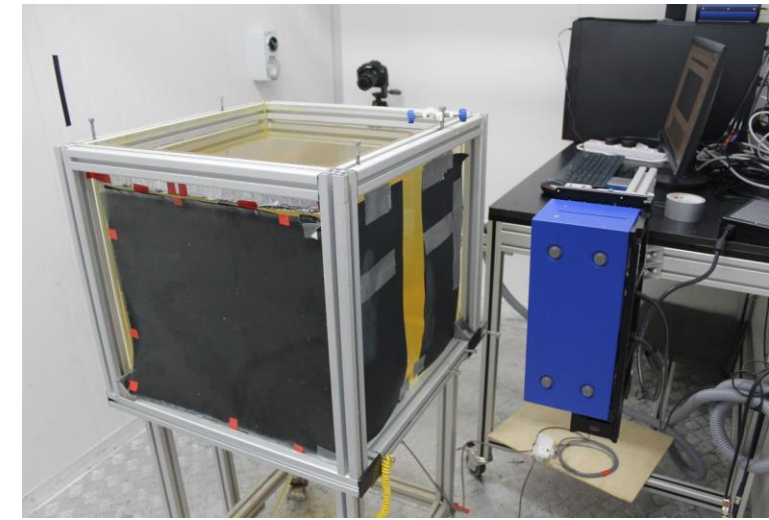
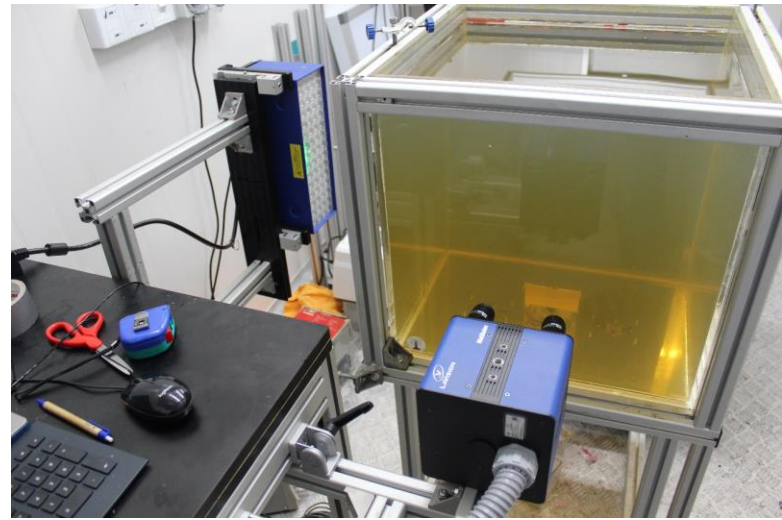
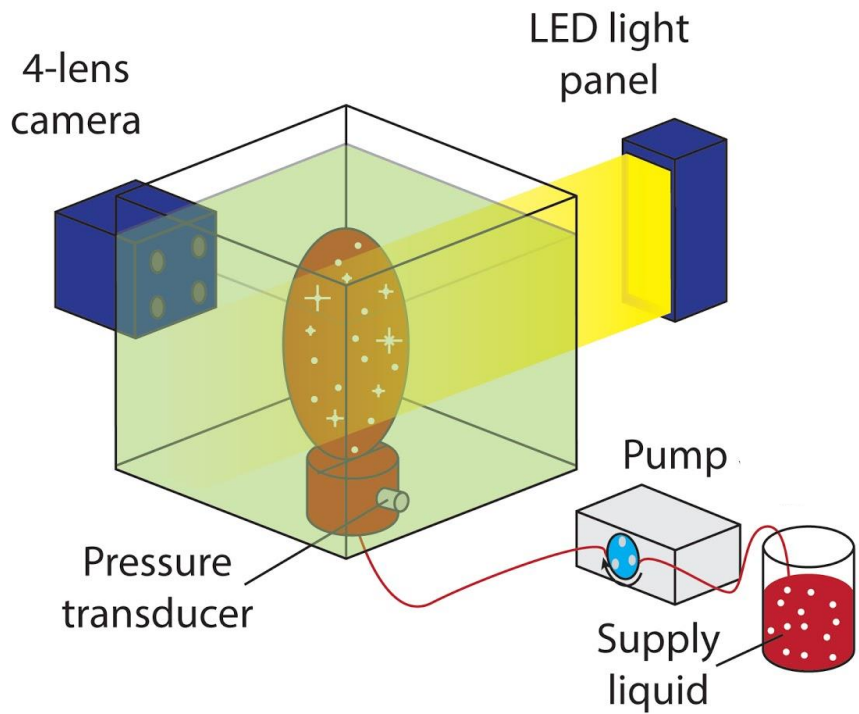
سرعت سنجی در سه بعد



General System Specifications

Digital output	10 bit
Interface	4x USB 3.0
Lens mount	4x c-mount
Number of cameras	4
Number of pixels	1984 x 1264 pixel (each camera)
Pixel size	4.8 μm x 4.8 μm
Spectral range	370 – 950 nm
Frame rates	121 fps @ full frame 200 fps @ 1600 x 940 pixel 510 fps @ 896 x 656 pixel 1000 fps @ 704 x 358 pixel

	MiniShaker L
Dimensions (L x W x H)	145 x 145 x 110 mm ³ w/o camera lens



Emadzadeh, A., Pansino, S., Manta, F. and Taisne, B., "Applications of image-based measuring techniques in understanding fluid-filled crack's dynamics in analog models", *Journal of Geophysical Research: Solid Earth*, (Under review).

