Lecture #27: Quantum Dots (DQ) Imaging for Thermal flow studies

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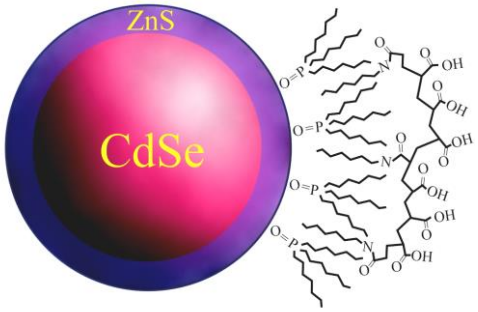
❑ Introduction about Quantum Dots

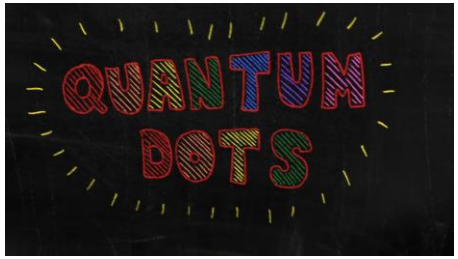
Quantum dots are chemically synthesized semiconductor nanoparticles that can exhibit unique quantum confinement behavior.

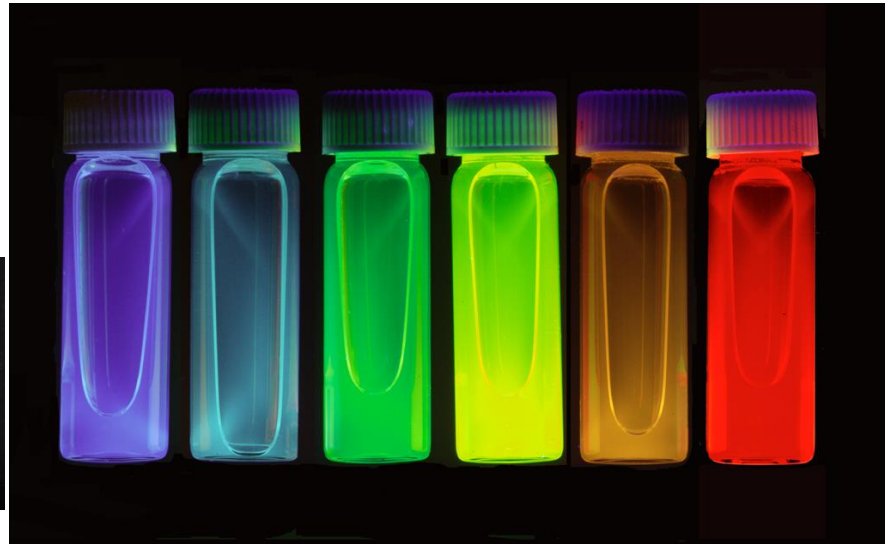
- *Size dependent emission:*
  - *Smaller particles emit high-energy (shorter wavelength) radiation*
  - *Larger particles emit low-energy (longer wavelength) radiation.*
- *Adjustable hydrophilic or hydrophobic properties:*
  - *The surface layer can be designed to be either hydrophilic or hydrophobic allowing the nanoparticles to be solubilized in a variety of liquids (i.e. polar and nonpolar).*

What's Quantum Dots



The structure of a (CdSe)ZnS quantum dot



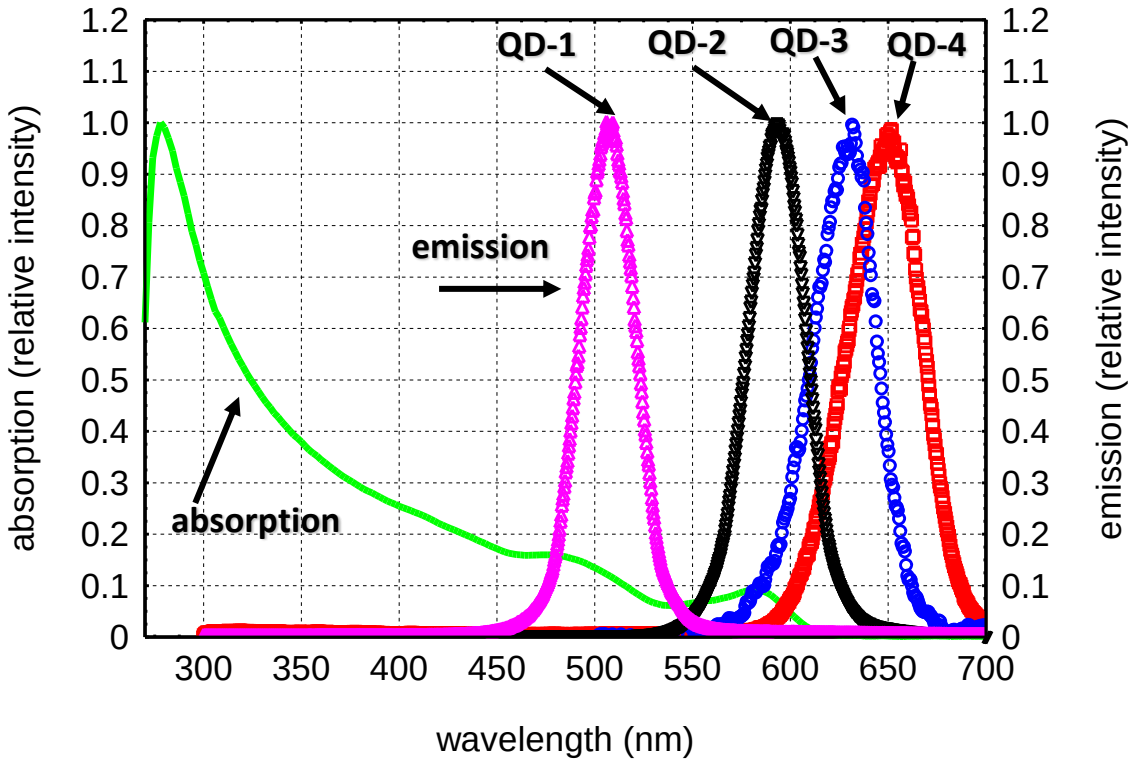


2.3nm → *5.5nm*

❑ Absorption and Emission Spectra of (CdSe)ZnS Quantum Dots

- *Absorption spectrum:*
  - *wide range of absorption*
  - *various laser can be used as excitation source*
- *Emission spectrum:*
  - *emission peak wavelength is adjustable by controlling the size of QDs*
  - *emission spectrum is symmetrical to the emission peak*
  - *emission concentrates near emission peak with FWHM only 30~40 nm*

Quantum Dots	Emission	
	Emission Peak	Full-Width Half-Maximum
QD-1	507 nm	33 nm
QD-2	593 nm	34 nm
QD-3	630 nm	36 nm
QD-4	650 nm	40 nm

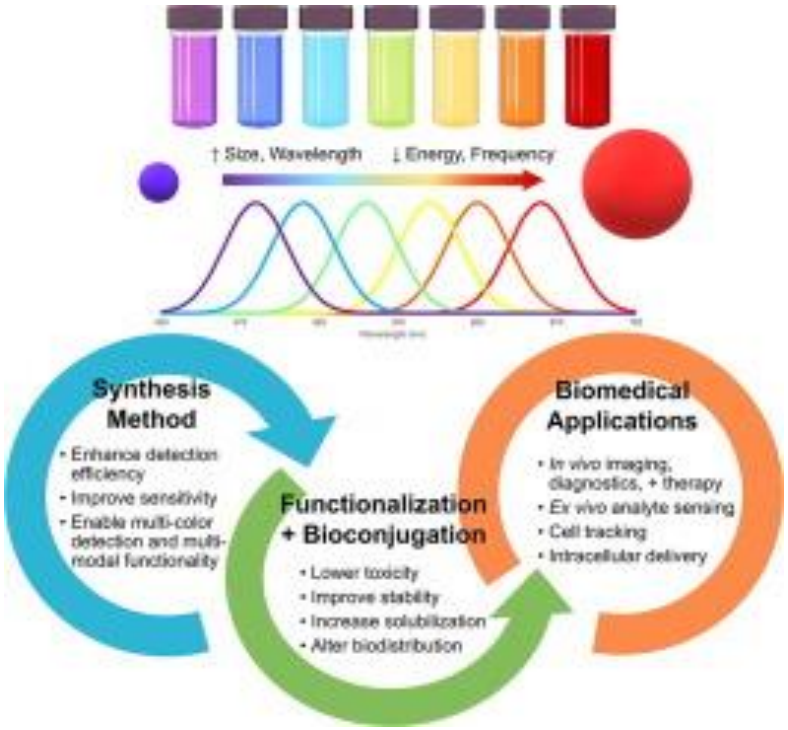


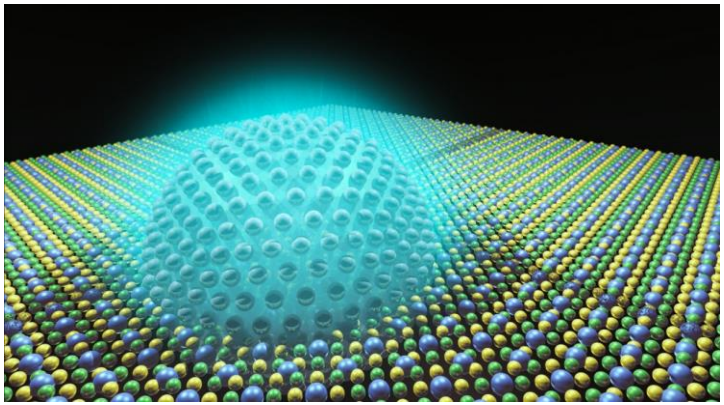
❑ Quantum dots (QDs) for Thermo-Fluids Measurements

- *The propose of the present study is to explore the possibility of Quantum dots (QDs) for thermo-fluids diagnostics.*

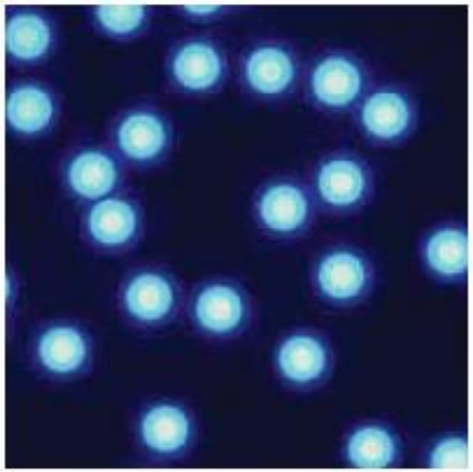
- *Compared to commonly-used fluorescent dyes such as Fluorescein and Rhodamine B, the photophysical properties of (CdSe)ZnS QDs will be investigated:*
  - *Absorption and emission spectra.*
  - *Stability against photobleaching under different laser excitations.*
  - *Temperature sensitivity under different laser excitations.*

- *The applications of QDs for thermal-fluids diagnostics*
  - *Individual QDs as particle tracers for velocimetry in micro flows:*
    - *Single Quantum Dot (QD) Velocimetry by Pouya et al. Experiments in Fluids, 2006.*
  - *QDs as fluorescent tracers:*
    - *Flow visualization and concentration measurements in a pulsed jet flow.*
    - *Temperature distribution mapping in a stratified flow.*

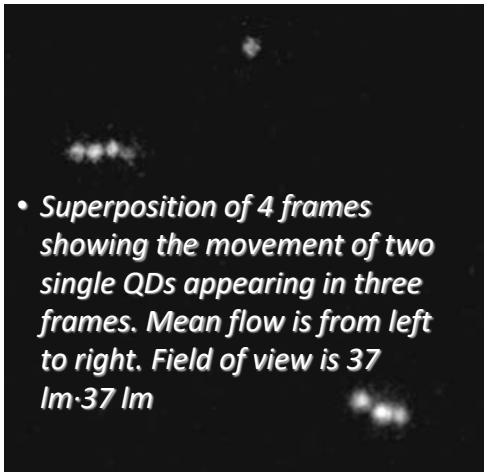




❑ QD imaging for flow velocity measurements

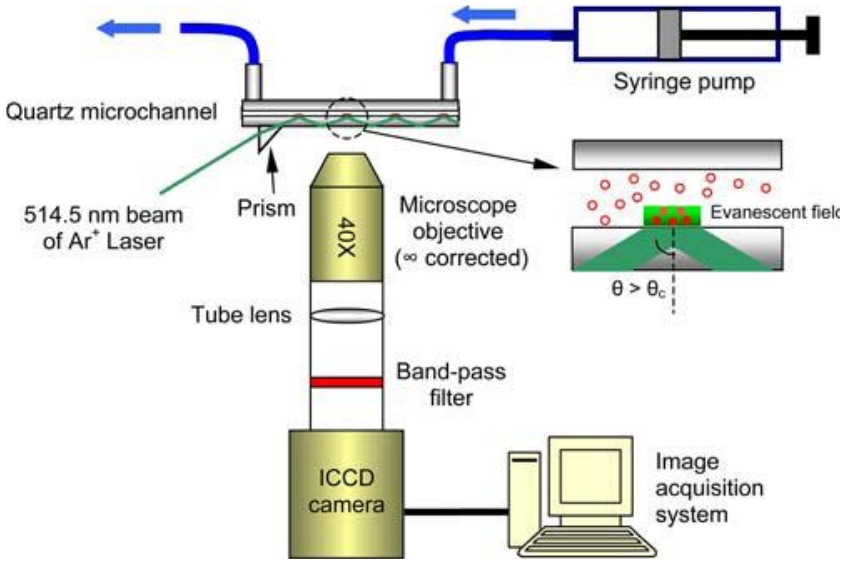


- *QD is much brighter than fluorescent nanoparticles for Micro-PIV measurements*



- *Superposition of 4 frames showing the movement of two single QDs appearing in three frames. Mean flow is from left to right. Field of view is 37 lm·37 lm*

- *Image of 6 nm (CdSe)ZnS quantum dots in aqueous solution within 100 nm of the surface. Field of view is 153 lm·93 lm*



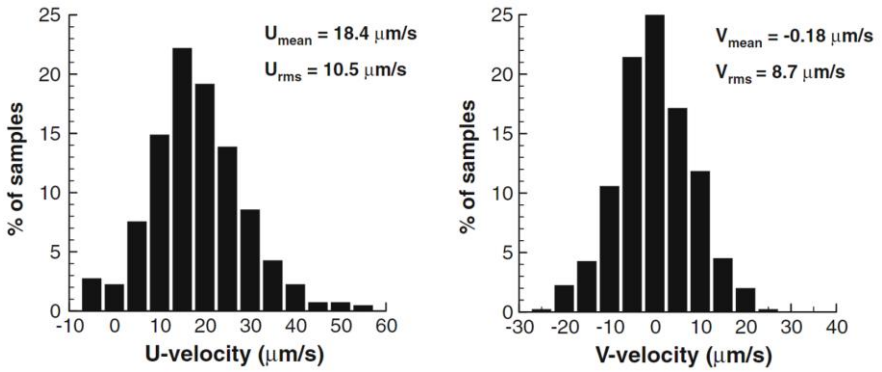
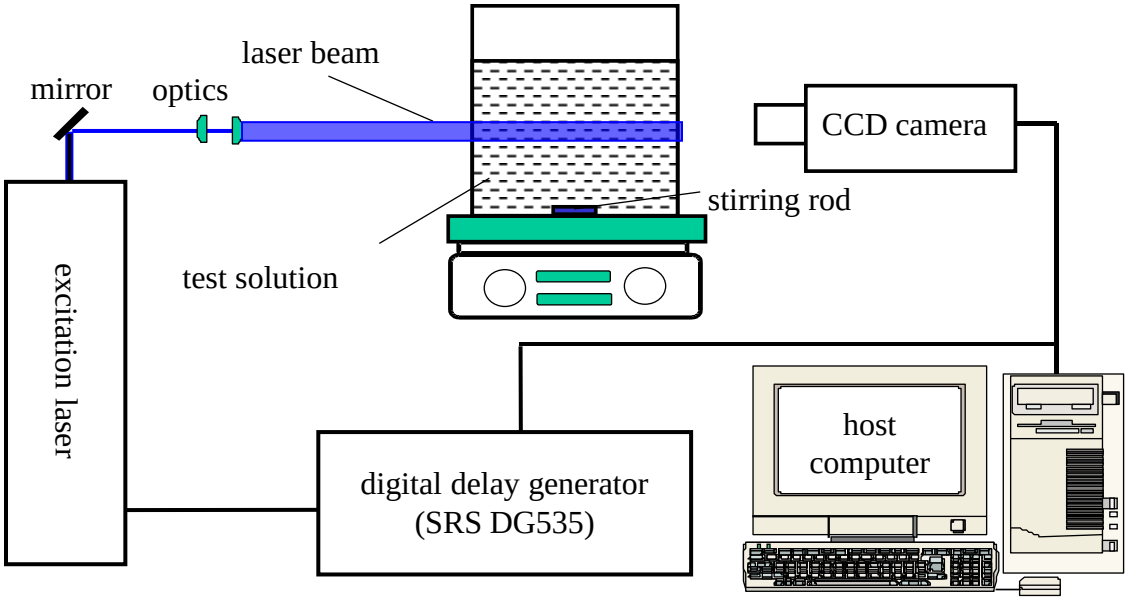


Fig. 4 Histogram of measured streamwise (U-component) and cross-stream (V-component) velocities in the illuminated plane

- *Shahram Pouya. Manoochehr Koochesfahani Preston Snee, Moungi Bawendi , Daniel Nocera, "Single quantum dot (QD) imaging of fluid flow near surfaces", Experiments in Fluids (2005) 39: 784–786*

❑ PHOTOPHYSICAL STABILITY AGAINST PHOTOBLEACHING

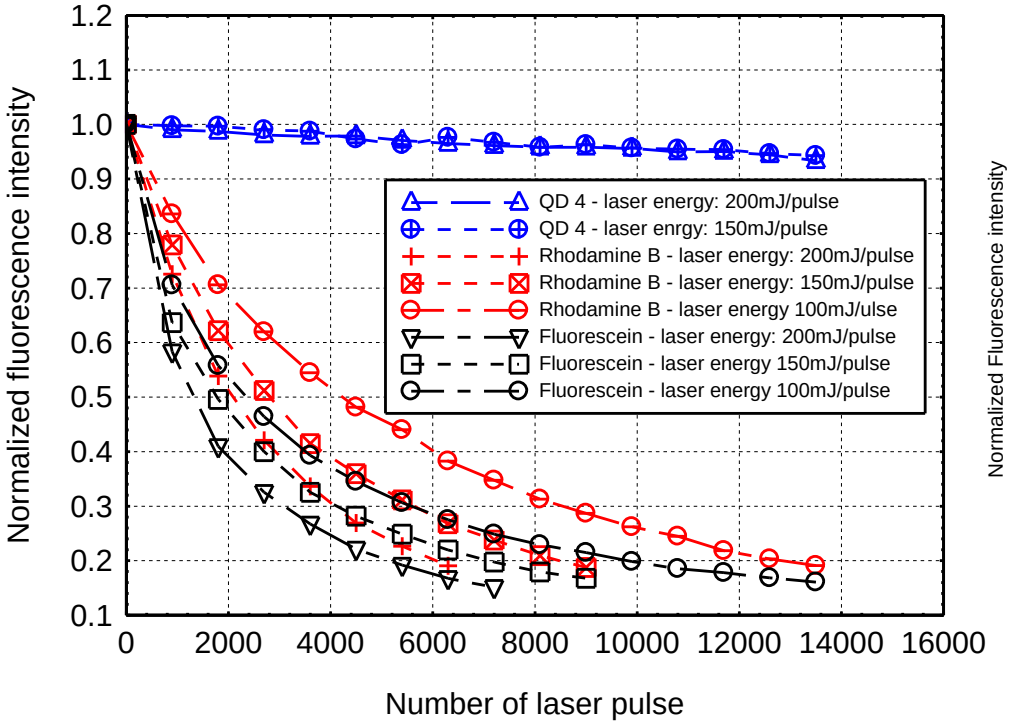
- ***Same volume (200ml) of QD, Fluorescein and Rhodamine B solutions were prepared.***
- ***Concentration of the Fluorescein and Rhodamine B aqueous solution is 1.0×10^{-6} M.***
- ***The solvent of QD is Hexane.***
- ***The absolute molar concentration of QD is unknown, but it has the same initial fluorescence emission intensity as the Rohdamine B -1.0×10-6 M solution.***

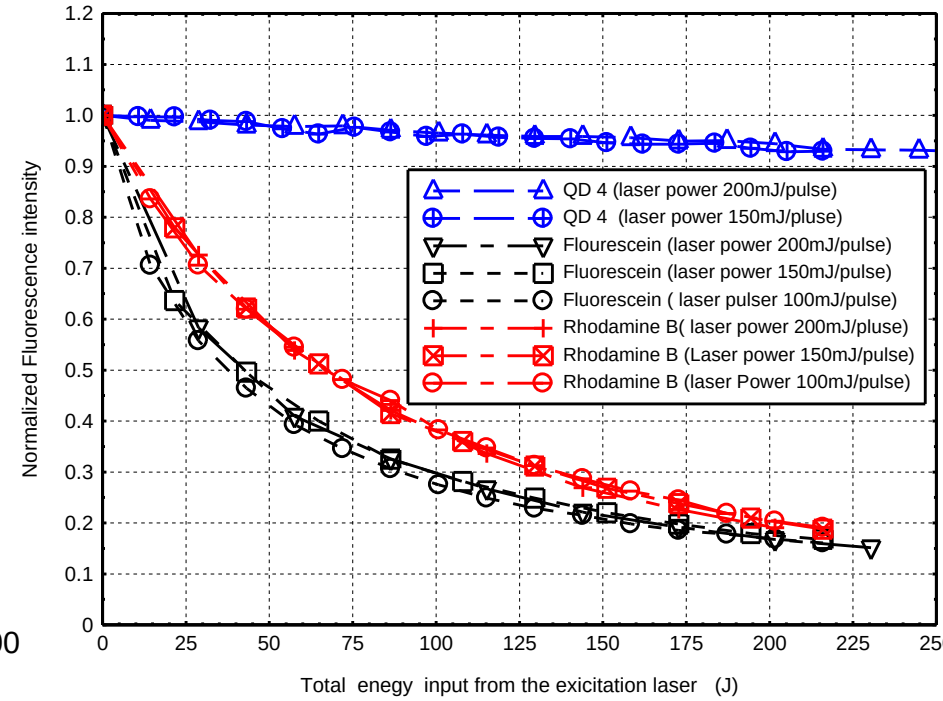


Experimental setup for the photoluminescence stability test

❑ Photoluminescence stability against photobleaching (Comparison of QD with Fluorescein and Rhodamine B)

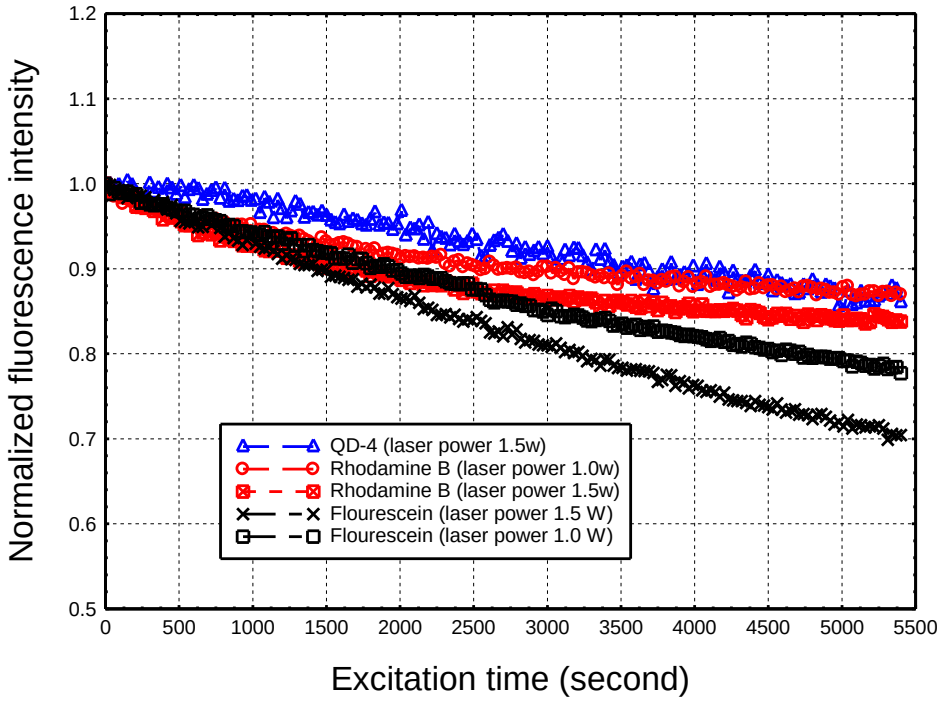
excitation laser source: pulsed excimer UV laser (308nm)

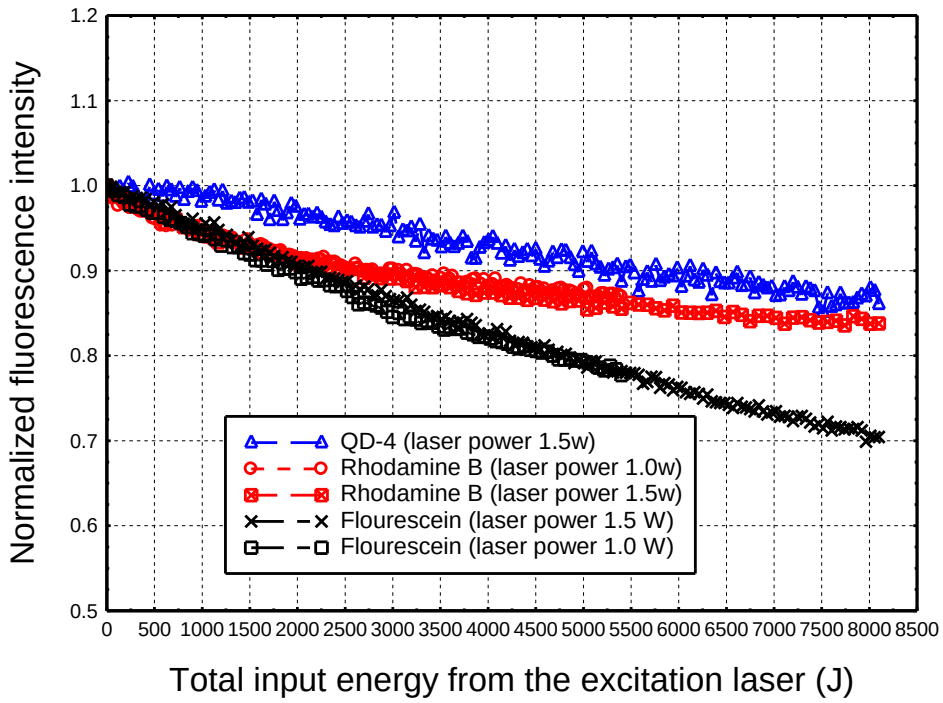




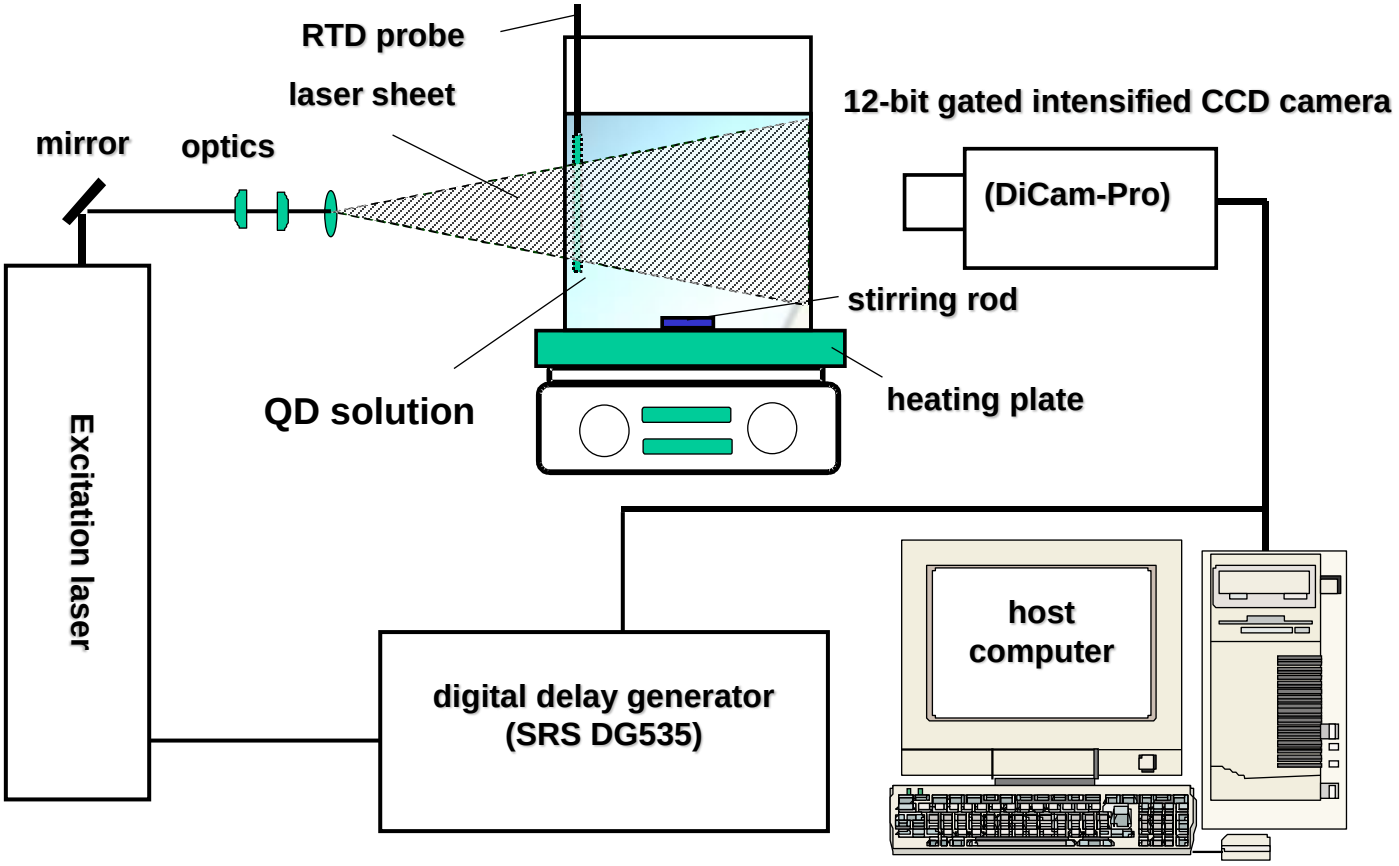
Photoluminescence stability against photobleaching (Comparison of QD with Fluorescein and Rhodamine B)

excitation laser source: Argon-ion laser (514.5 nm)



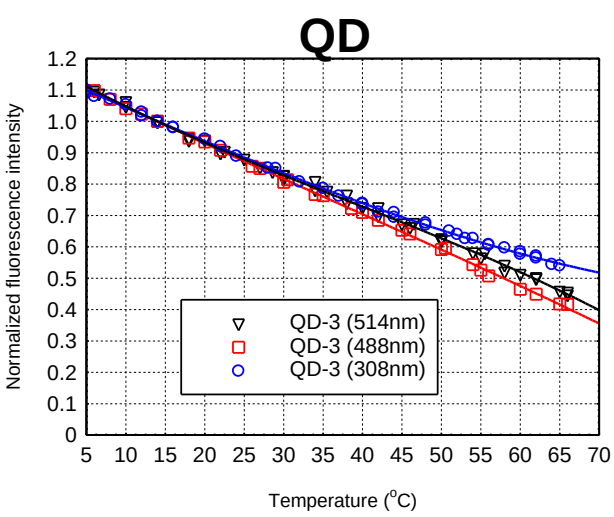


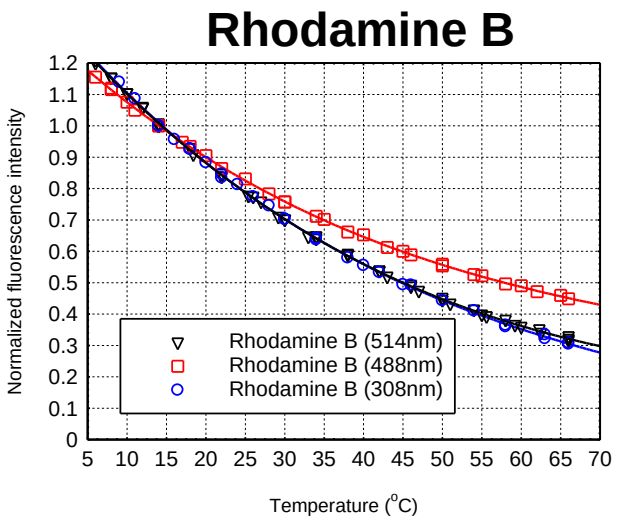
Temperature Sensitivity Test

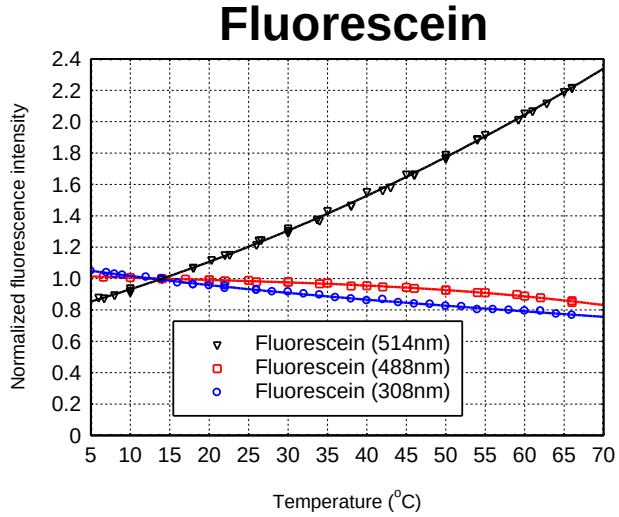


Experimental setup for temperature sensitivity test

Temperature sensitive of QD, Fluorescein and Rhodamine B

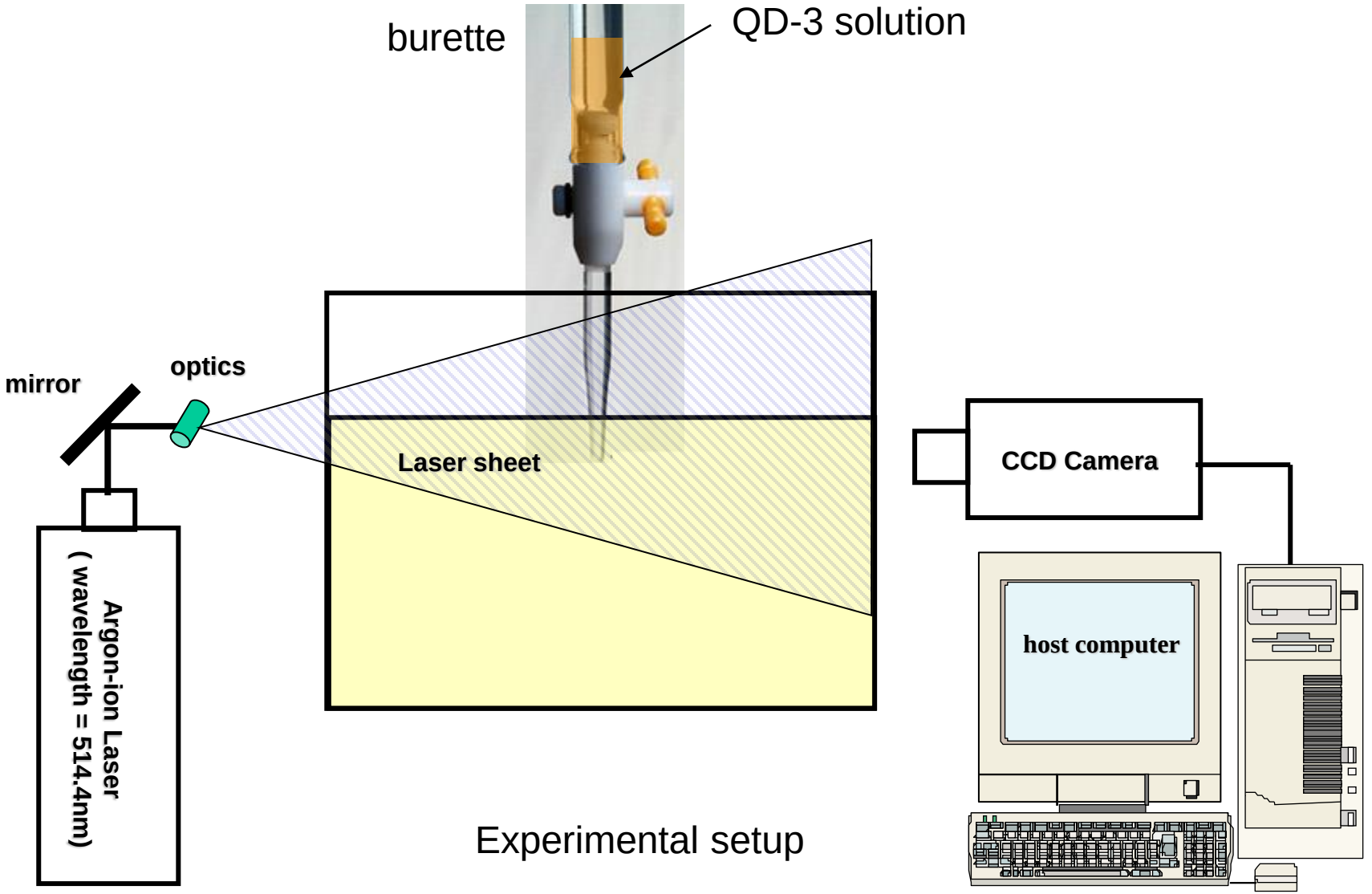






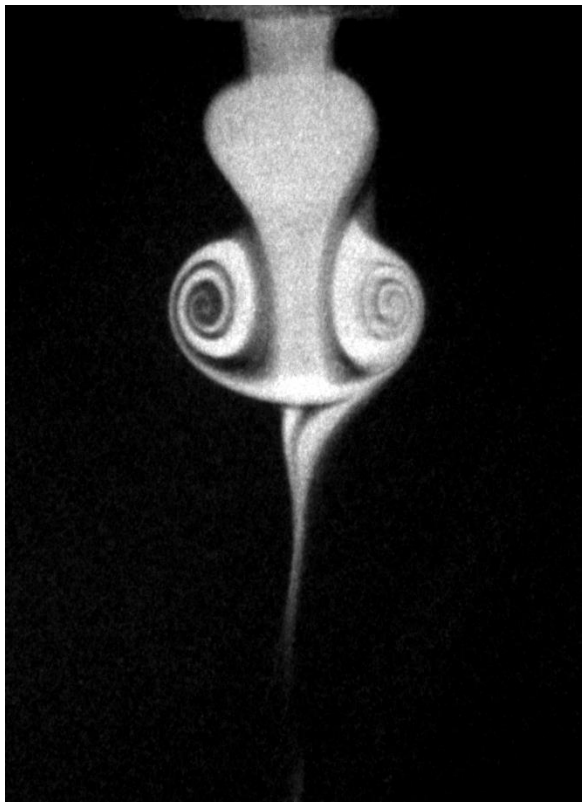
	308nm Excimer laser	488nm Argon-ion laser	514nm Argon-ion laser
QD-3	-0.94% per ^{0}C (5^0C ~ 65^0C)	-1.14% per ^{0}C (5^0C ~ 65^0C)	-1.05% per ^{0}C (5^0C ~ 65^0C)
Rhodamine B	-1.57% per ^{0}C (5^0C ~ 65^0C)	-1.20% per ^{0}C (5^0C ~ 65^0C) Kim & Khim (2001) -1.35 % per^0 C (15^0C ~ 40^0C)	-1.52% per ^{0}C (5^0C ~ 65^0C) Coppeta & Roger(1998) -1.54 % per^0 C (20^0C ~ 60^0C)
Fluorescein	-0.45% per ^{0}C (5^0C ~ 65^0C)	-0.25% per ^{0}C (5^0C ~ 65^0C) Coppeta & Roger(1998) -0.16 % per^0 C (20^0C ~ 60^0C)	+2.25% per ^{0}C (5^0C ~ 65^0C) Coppeta & Roger(1998) +2.43 % per^0 C (20^0C ~ 60^0C)

Application Quantum Dots for Thermal-Fluids Diagnostics (Concentration Measurements in a Pulsed Jet)

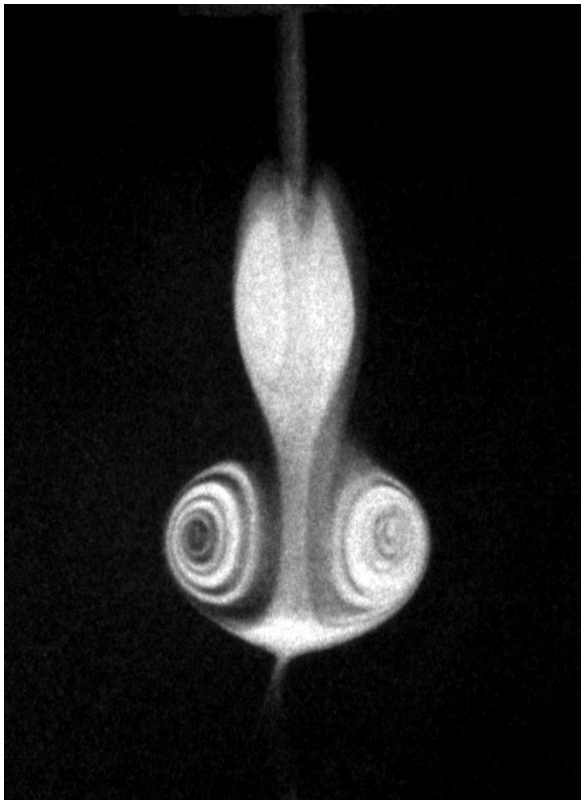


Experimental setup

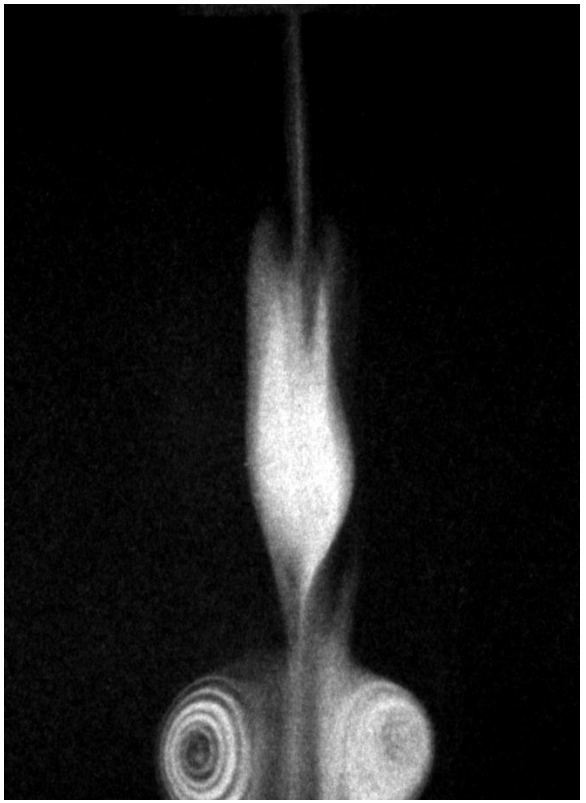
Application Quantum Dots for Thermal-Fluids Diagnostics (Concentration Measurements in a Pulsed Jet)



a. $t = t_0$

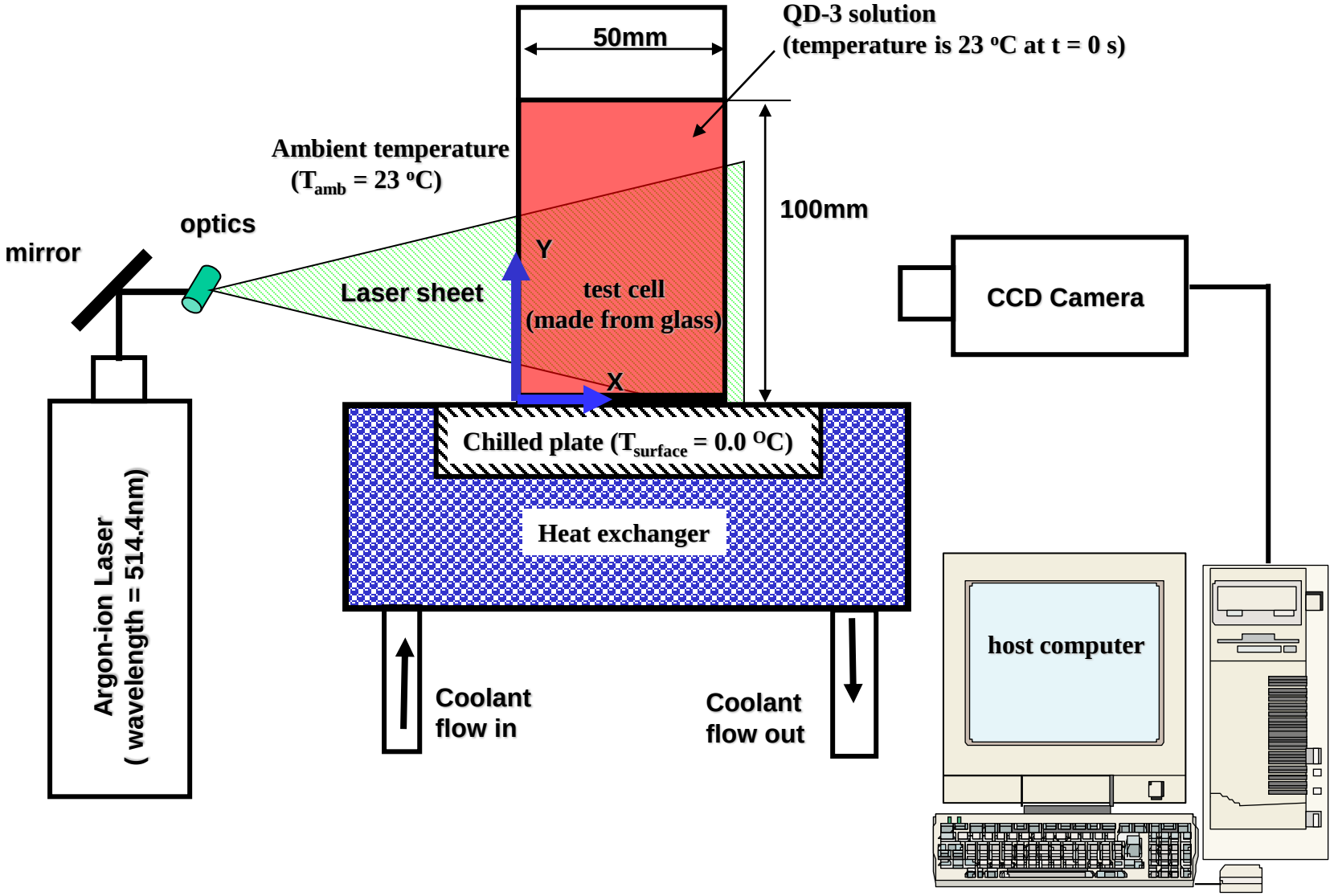


b. $t = t_0 + 0.2$ s

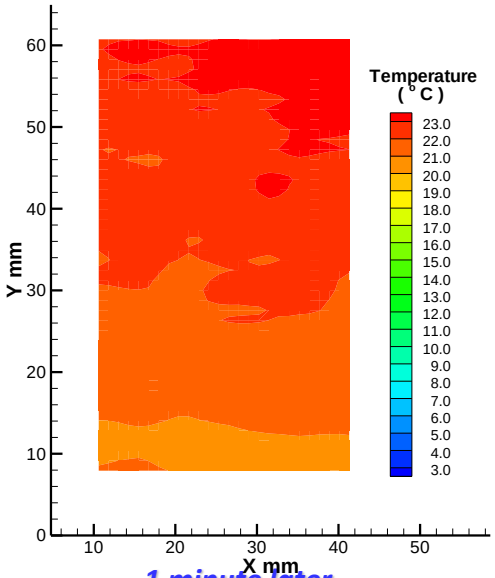


c. $t = t_0 + 0.4$ s

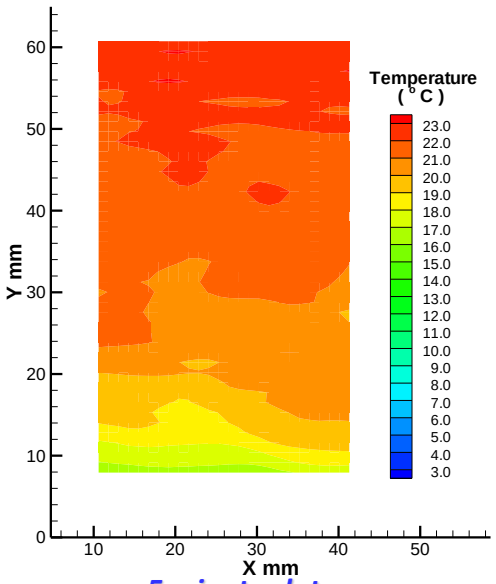
Application Quantum Dots for Thermal-Fluids Diagnostics (Temperature measurements in a Stratified Flow)



Application Quantum Dots for Thermal-Fluids Diagnostics (Temperature measurements in a Stratified Flow)



1 minute later



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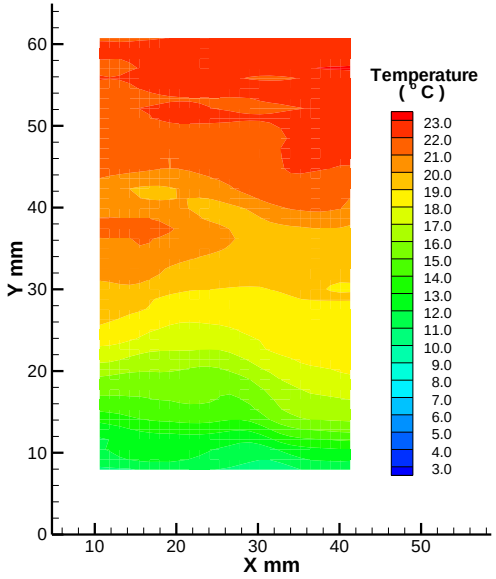

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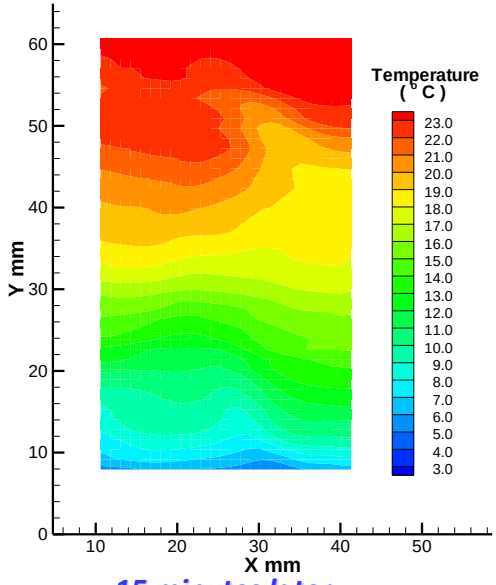

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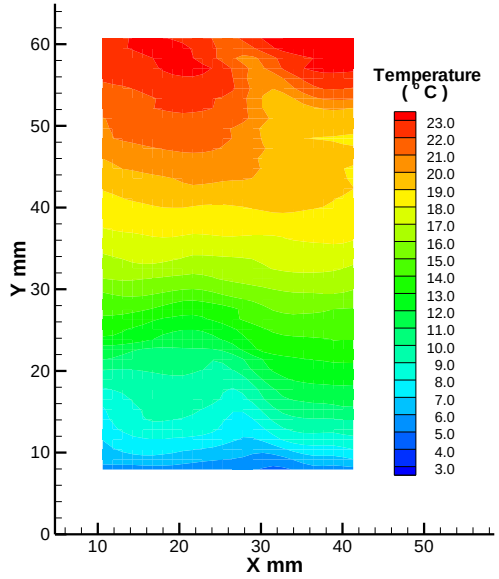

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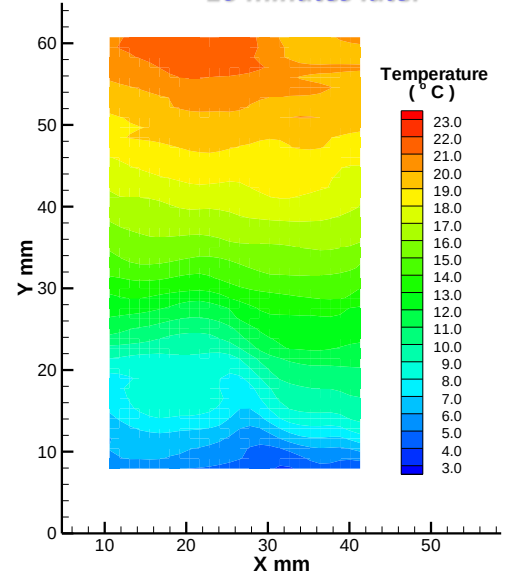
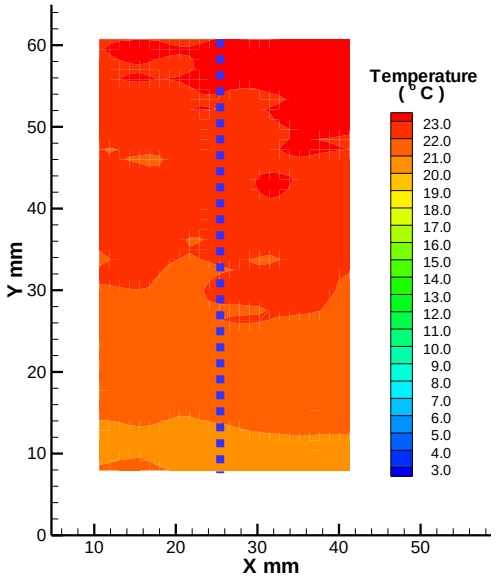
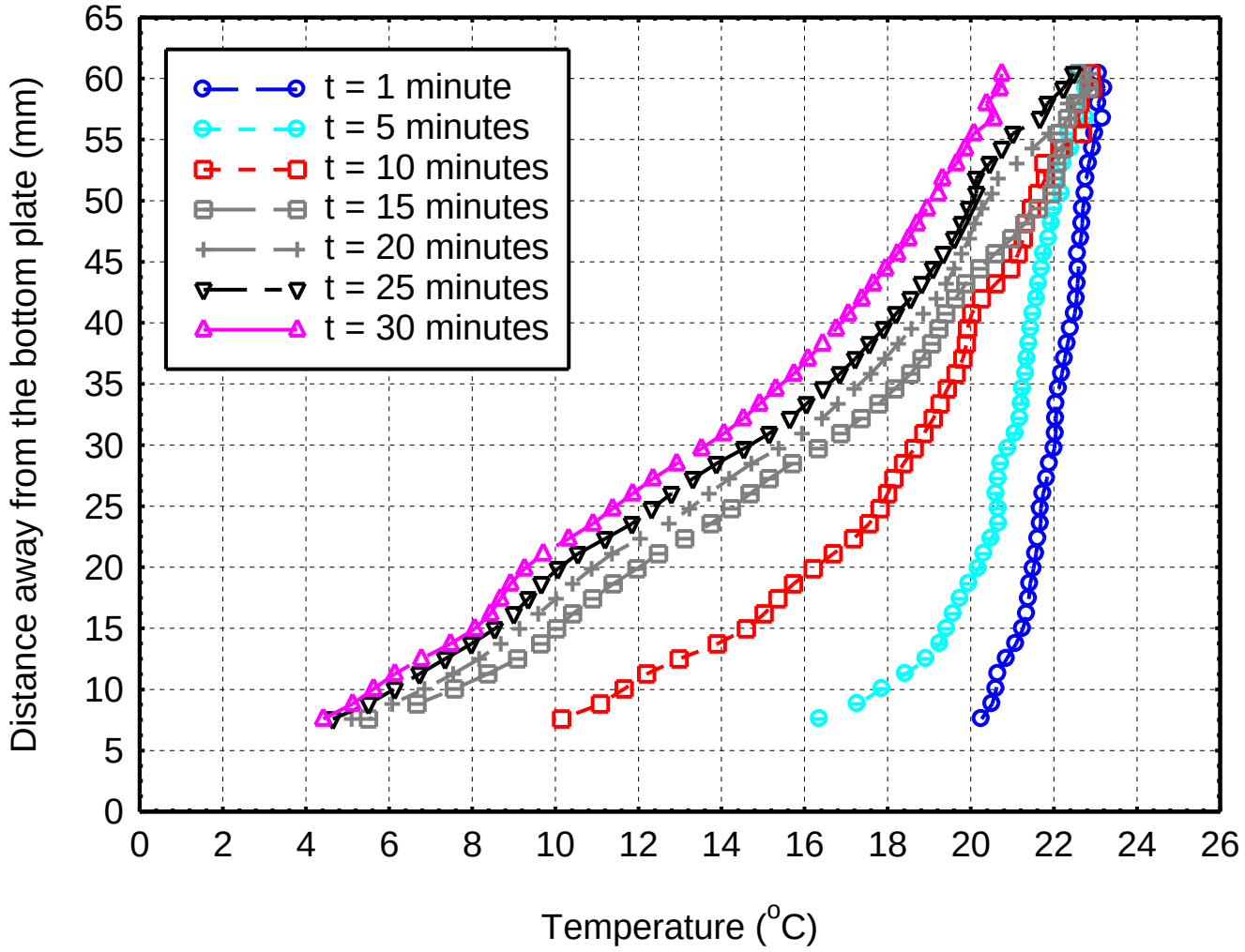


30 minutes later

Application Quantum Dots for Thermal-Fluids Diagnostics (Temperature measurements in a Stratified Flow)





Temperature profiles along the vertical line in the center of the test cell.