4th Japan-Korea Joint Seminar on Particle Image Velocimetry
Sept. 29-Oct.1, 2006, Kobe, Japan,

Index-Matching PIV for Complex Flow Geometry

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Outline

Application of PIV technique to industrial flow problems often requires the resolution of fluid behavior in very complex flow geometry. Good examples are the flows in an internal combustion engine, those around intake and exhaust valves, those through an impeller of rotating machinery, those in fin-tube geometry of heat exchangers and so on. The existence of opaque and curved walls in such examples presents a challenge for the PIV technique that needs an undisturbed optical access for both imaging and lighting. Conventional approach to avoid this problem is to make an effort based on case-by-case consideration of the flow geometry and flow condition. This approach has, however, been limiting the range of applicability of PIV technique and resulting in costly burden in the design of flow measurement.

The authors have developed a new approach that can solve the problem mentioned above and therefore expand the applicability of PIV technique to complex flow geometry. The approach is based on the use of index-matching and rapid prototyping. Perfect matching of refractive indices between the working fluid and the flow model provides an optical access for imaging and lighting adequate for PIV. Such an approach was reported by one of the authors (Nishino et al. 2004) who used the glycerol solution and a silicone-rubber model for index matching. The model was made through rapid prototyping from three-dimensional surface data of a cerebral aneurysm of a real patient. This approach has been extended in the present study so that engineering models made of plastic material (acryl, urethane and epoxy) can be utilized for index matching. Such models are fabricated from their three-dimensional CAD data through laser modeling, numerical-controlled machining or vacuum casting.

In this seminar, a stereo PIV measurement is presented for a liquid-flow model of an internal combustion engine made of acrylic resin. The working fluid is zinc iodine solution for index matching with the model. It is shown that the present approach is quite effective to reveal three-dimensional flow behaviors in complex geometry seen in many industrial flow problems.

Reference

Nishino, K., Kawaguchi, D., Kosugi, T and Isoda, H., 2004, Highly Efficient PIV Measurement of Complex Flows Using Refractive Index Matching Technique, CD-ROM Proc. 2004 Korea-Japan Joint Seminar on Particle Image Velociemtry, POSTECH, Korea, Dec. 9-10.

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Background

(1) Very complex flow geometries in engineering and biomedical applications often impose severe limitations on PIV.

(2) In practice, more efforts & costs are needed to solve/avoid such limitations than to conduct PIV measurements.

(3) A good solution for this problem should enhance the usefulness of PIV technique.

Objectives

(1) To propose a new approach for efficient PIV measurement of complex flows by combining rapid prototyping (RP) technique and refractive index matching (RIM) technique.

→ limited to liquid flows

(2) To demonstrate the proposed approach by measuring complex turbulent flows in an ICE model with stereo PIV technique.

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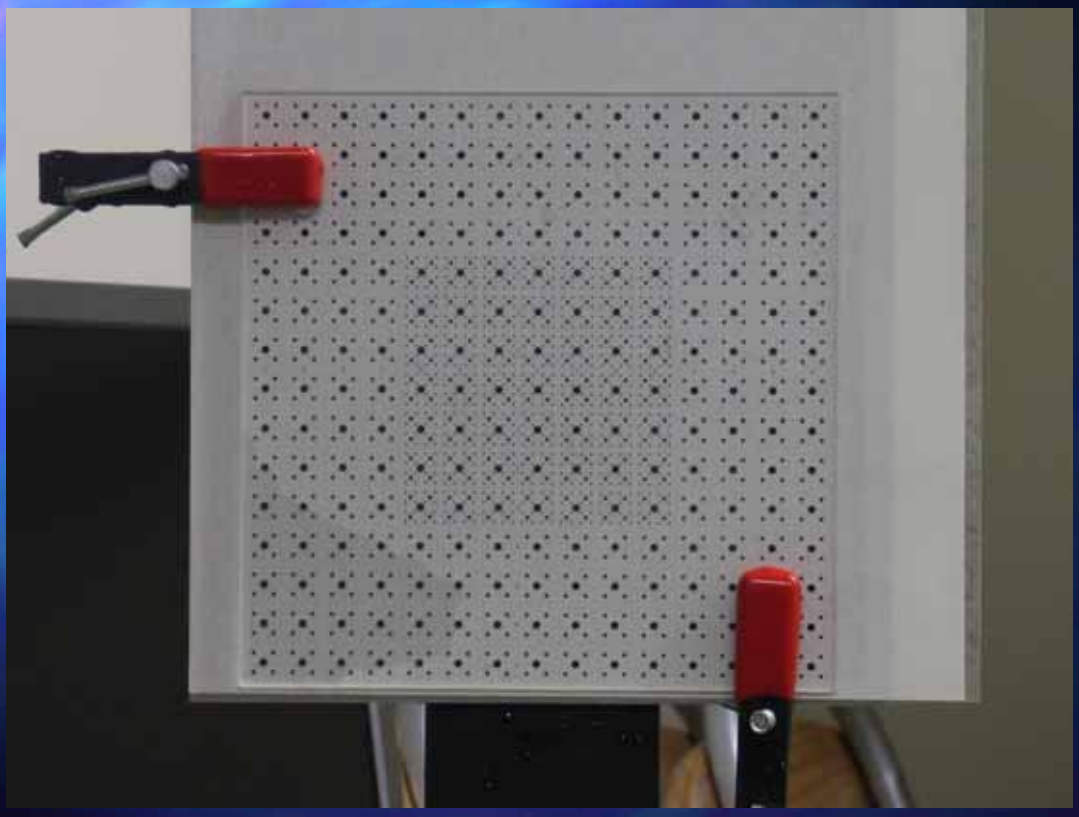
Materials and Fluids for Index Matching

Model Materials	n
Pyrex	1.47-1.49
Acryl	1.49-1.53
Urethane	1.51-1.54
Epoxy	1.55-1.57
Silicone rubber	1.40-1.43

Working Fluids	n
Glycerol solution	1.33-1.47
Zinc iodine solution	1.33-1.62
Sodium iodine solution	1.33-1.50
Kerosin	1.45
Mineral oil	1.48
Olive oil	1.47

Budwig (1994)

Calibration Plate



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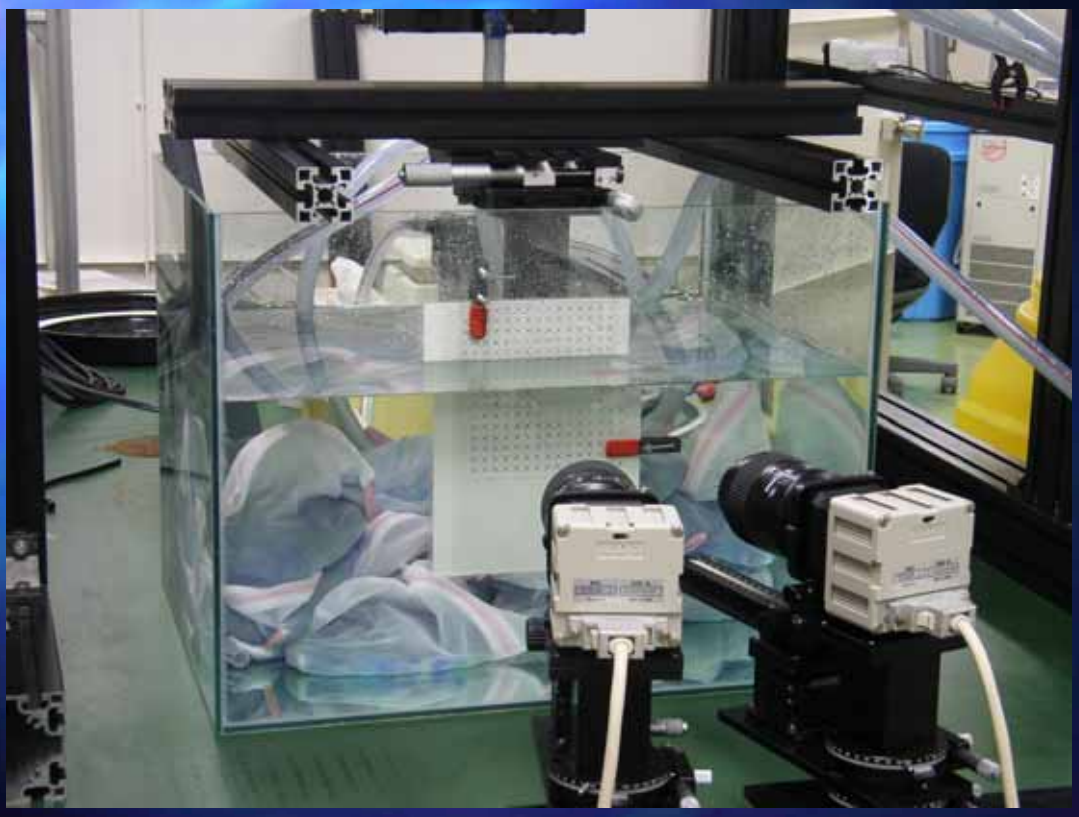
Camera Calibration



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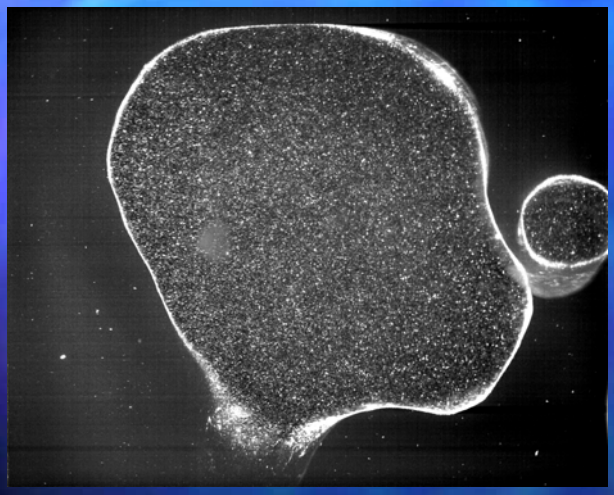
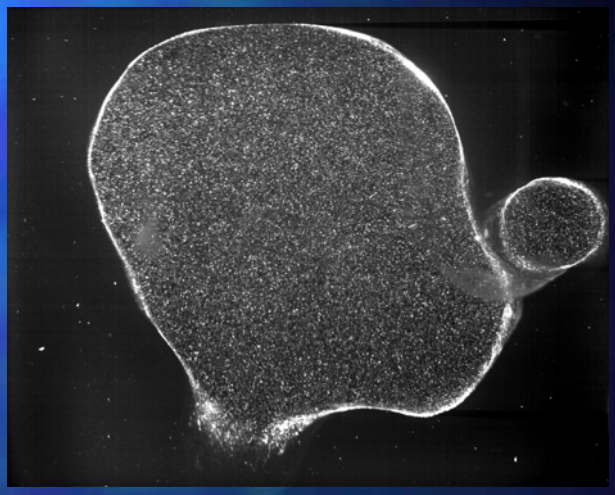
Particle Images (Stereo Pair)





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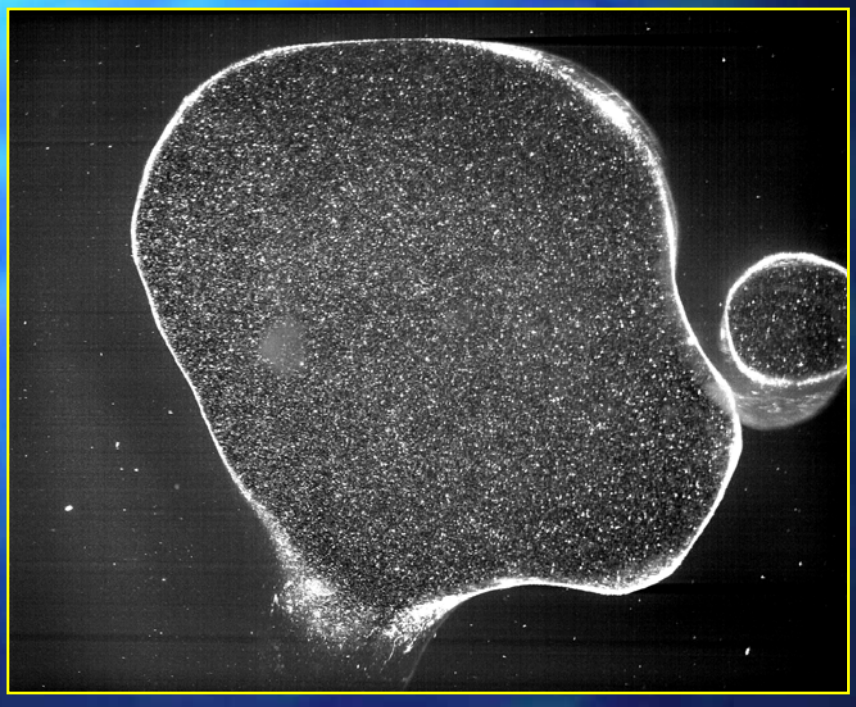
Back-projected Particle Images (Left)



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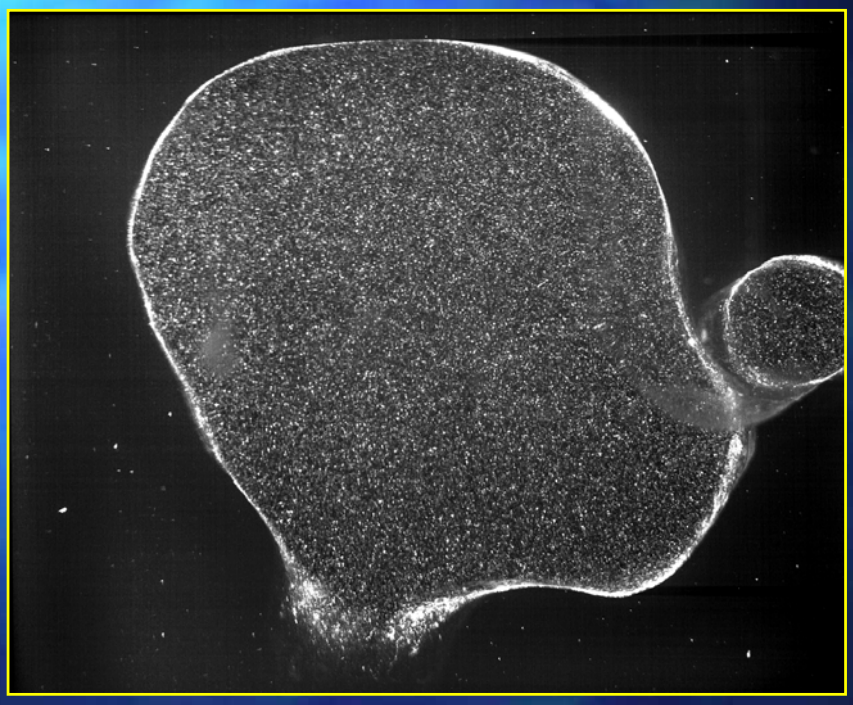
Back-projected Particle Images (Right)



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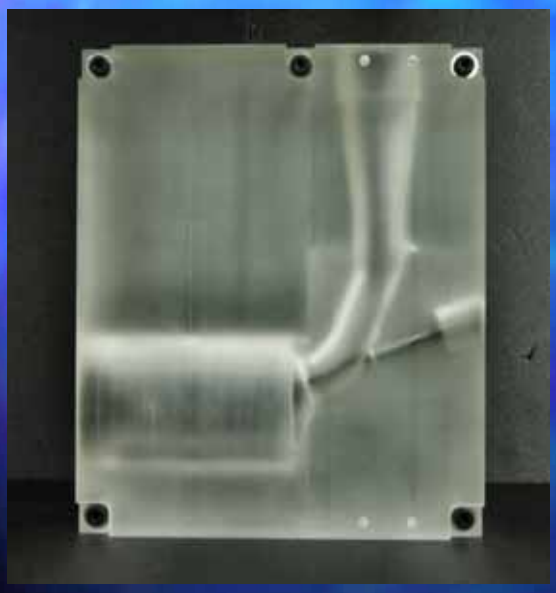
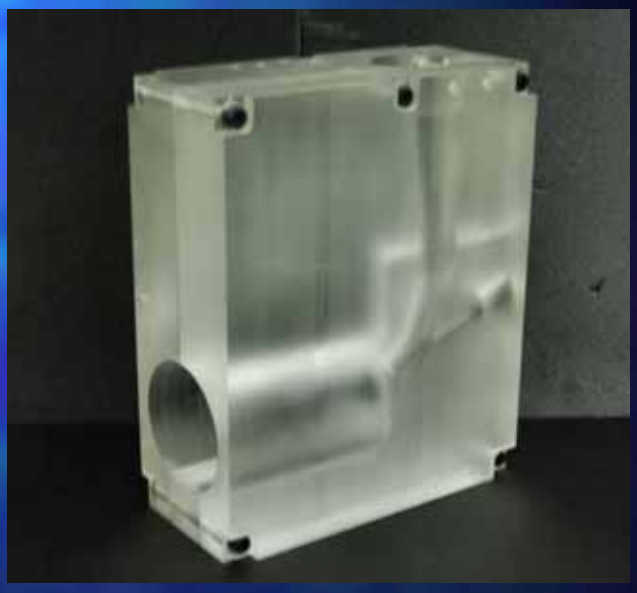
Acrylic ICE Model





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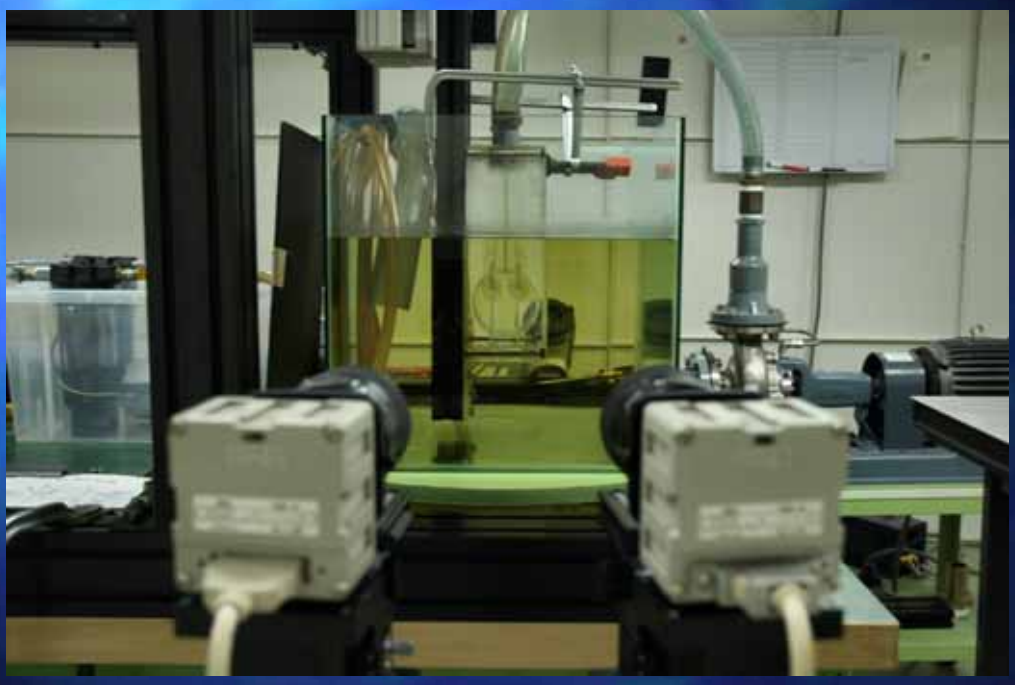
Model and Working Fluid in Index Matching



Model and Working Fluid in Index Matching

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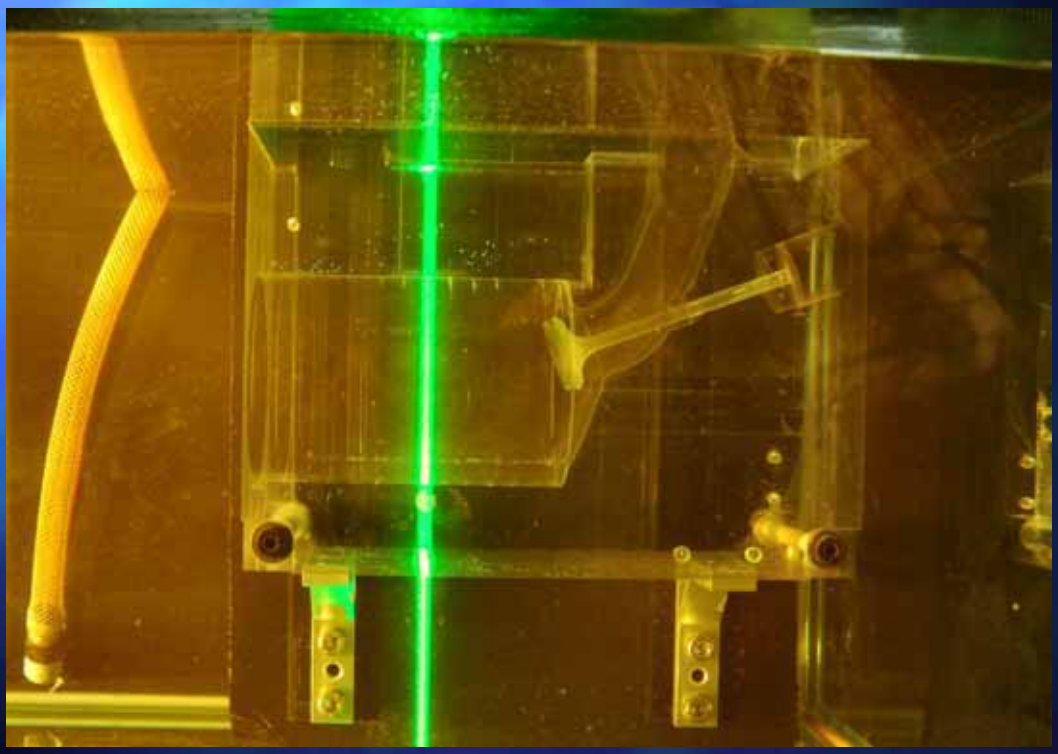
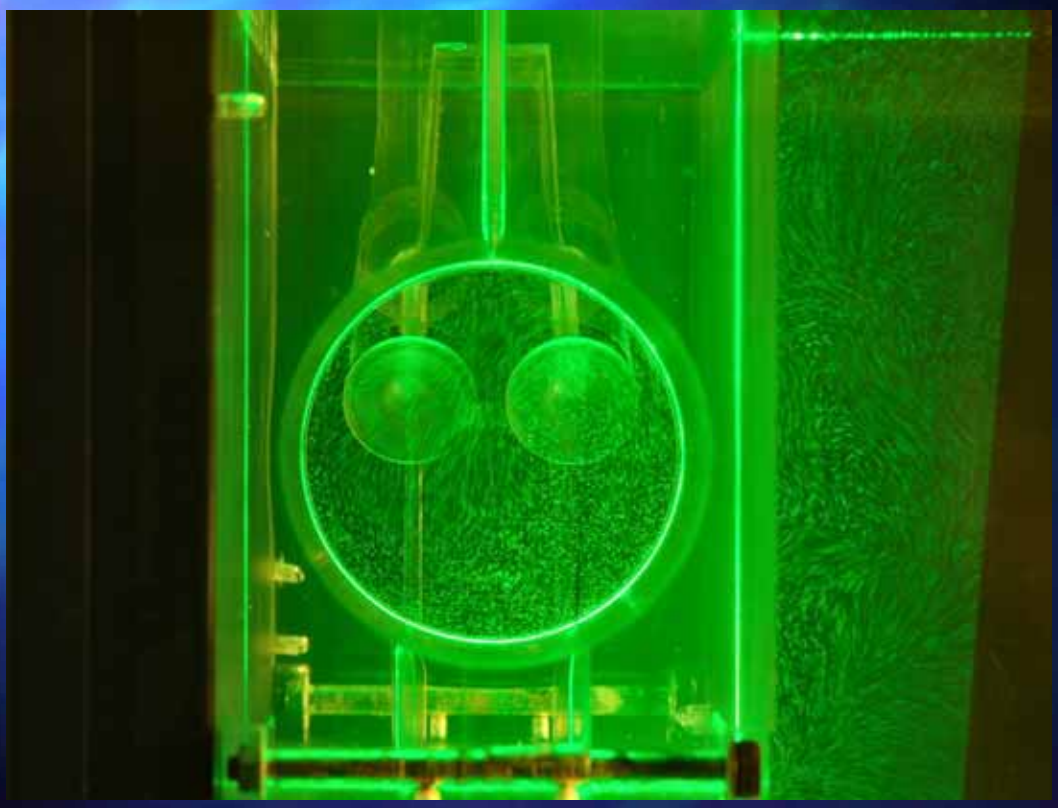


Cross-sectional View and Particle Images



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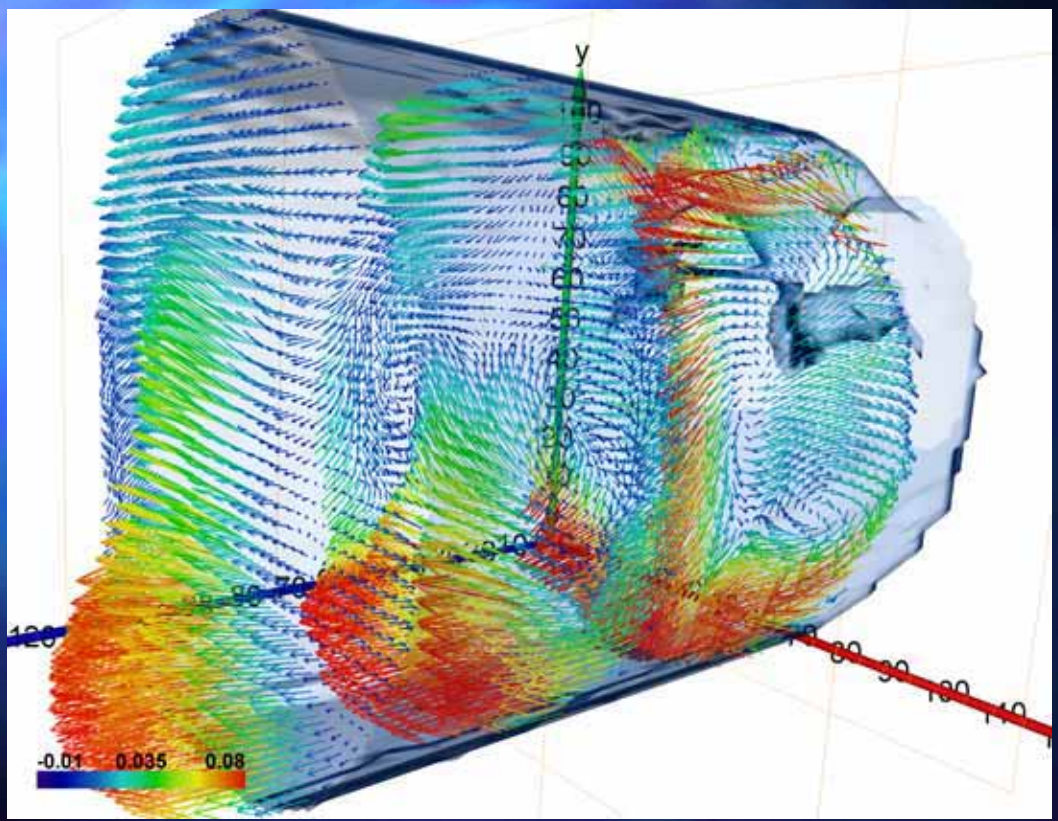
3-D Plot of Mean Velocity Field



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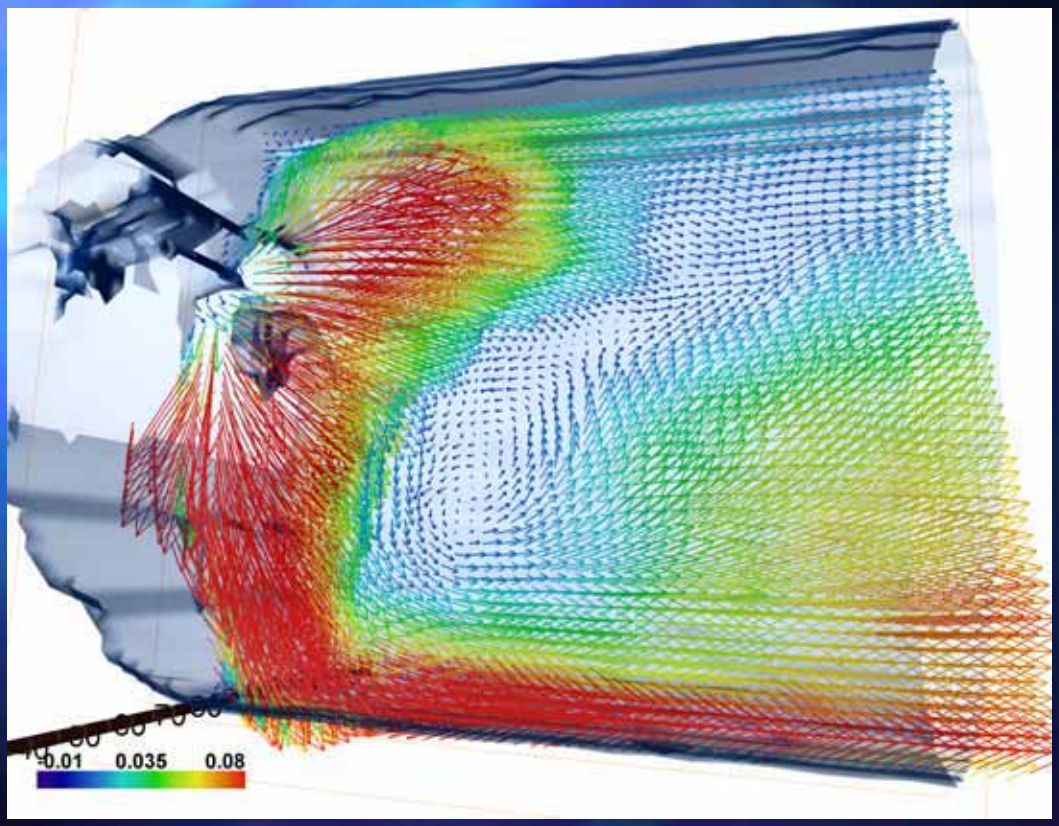

Summary

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(1) A new approach based on combining rapid-prototyping and index-matching techniques is proposed for efficient PIV measurement of complex flows.

(2) The usefulness and efficiency of the proposed technique is demonstrated in the stereo PIV measurement of an ICE model made of acrylic resin.

This work is supported by
Japan Science and Technology Agency (JST)