Membership in Professional Societies:

- National Fluid Mechanics and Fluid Power – Life Member 2013 – Present
- Member International Society of Intelligent Unmanned System (ISIUS)

(B) Technology Products/Patents:

- "Ornithopter", Patent number 59/DEL/2015 J Bhowmik, and D Das

- A foldable wing design of an improved flapping wing aerial vehicle", (filed November 08, 2016) . Application number 201611038098, J Bhowmik, G Seth and D Das

- A system for particle generator in PIV applications (Patented) Application No.4I30/DEL/20I5 A (published in the Official Journal No. 25/2017 of the Patent Office dated 23-06-2017.)

- ' Novel Quadrotor Convertiplane Unmanned Air Vehicle', Patent applied ,Feb. 2017, Abhishek, Krishna, R., Sinha, S., Bhowmik, J. and Das

- Development of a LED based low cost Particle Image Velocimetry (PIV) System for BARC.

- Developed a Background Oriented Schlieren (BOS) System for density measurement.

- Developed a Planar Laser Induced Fluorescence (PLIF) system for species concentration measurements.

  Details of the above prototypes/instruments are given below.

- **Design and fabrication of Flying Ornithopters**
  Several flying ornithopters of different sizes, endurances and payloads have been successfully designed and built. The 0.5m and 1m wing span ornithopters can fly for 12mins and 35mins respectively. The 1.6m wing span ornithopter developed at present is having best endurance (60mins) parameters of such class UAV across the world. A hovering ornithopter for confined space operation is also developed. These UAVs were demonstrated for Indian Army in Udhampur, of Jammu and Kashmir. Documentaries on flapping UAVs of IIT Kanpur appeared in several prominent news channels and newspapers.

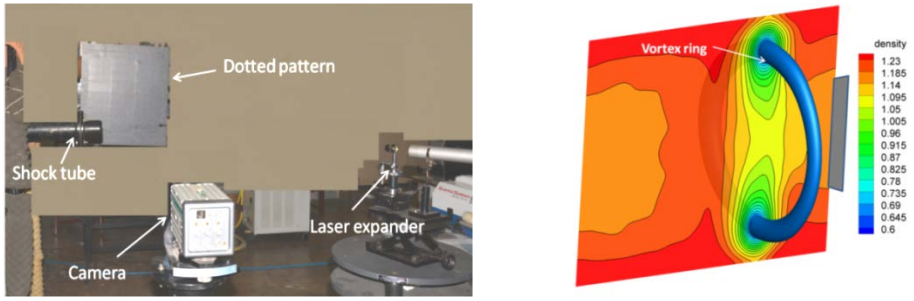
Weight : 30 g
Span of each wing =25cm
Endurance: 10-12 mins
Design Cruise speed : 6 m/s

Weight : 260 g
Span of each wing =50cm
Endurance: 30-35 mins
Design Cruise speed : 6 m/s

- **wingspan 1.6m**
- **Dry Weight :400 grams**
- **Endurance : more than 1 hour with 2 batteries(1000mAh each 3cell)**
- **Cruise speed: 6 to 8 m/s**

- **Background Oriented Schlieren Technique**
  Background Oriented Schlieren(BOS) is a whole field density measurement technique for an inhomogeneous density medium. It evaluates the density information by comparing the distortion of a deliberate background pattern with and without a density

medium. Even though other density visualization techniques such as schlieren, shadowgraphy and interferometry provide density information, they are laborious to set up and require expensive optics. In particular, they are limited to laboratory scale measurements. On the other hand, BOS uses only a digital still camera, a structured background and a light source for illuminating the background. The main advantage of BOS system is that it can be readily applied to large scale experimental set-ups with a minimal optical arrangement. An in house MATLAB based algorithm for evaluating the deflections of light rays is developed. From deflections, the projected density field is obtained by solving a Poisson solver. Inverse tomography algorithms are then employed to reconstruct the density field from projections. The following figure shows the BOS arrangement in an open-ended shock tube flow.



(a) (b)

Figure: (a) BOS arrangement for open-ended shock tube flows developed with C. L. Dora (Ph D Student) (b) Axisymmetric density field of a compressible vortex ring obtained from single projection at shock Mach number (M)=1.3.

- **Inexpensive seed generator for Particle Image velocimetry**

Particle Image Velocimetry (PIV) is mostly used technique for measuring fluid velocity in a region. It mainly relies on measuring the velocity of seed particles thereby the velocity of the fluid, presuming the particles follow the fluid motion. Typical commercial seed generators for air flows costs about approximately 2000 to 2500 USD. An inexpensive seed generator using the principle of atomization of vegetable oils is developed. A complete development of the seed generator costs about 20 to 30 USD approximately. All vegetable oils are less hazardous and can be directly used in this generator.

Figure: Inexpensive seed generator for PIV developed with C. L. Dora, K. K. Bharadwaj (Ph D Students), Particle image of a vortex ring obtained using inexpensive seed generator

- **Development of a low cost Particle Image Velocimetry (PIV) System**

Particle Image Velocimetry (PIV) is a modern tool of velocity measurements which can provide two or three components of velocity in a plane. Usually, PIV systems are expensive and a pulsed laser accounts for half of the cost of the system. The aim of this work is to replace the laser using an inexpensive and effective pulsed light source to

reduce the cost of the PIV system. Laser was successfully replaced by a pulsed LED light source. The LED could be externally controlled and synchronized with a camera using a pulse delay generator.

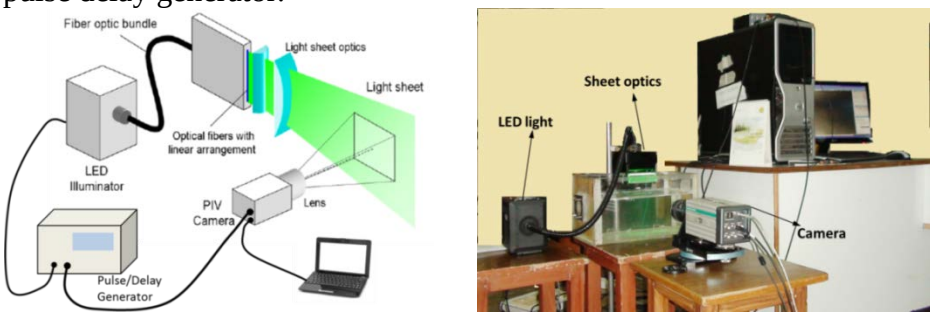


Figure: (a) Schematic of low cost PIV system (b) Experimental set-up

The developed PIV system has been used to measure velocity field in the wake of a circular cylinder. Developed with C. L. Dora, Saurav Ghosh and K. K. Bharadwaj (Ph D Students)

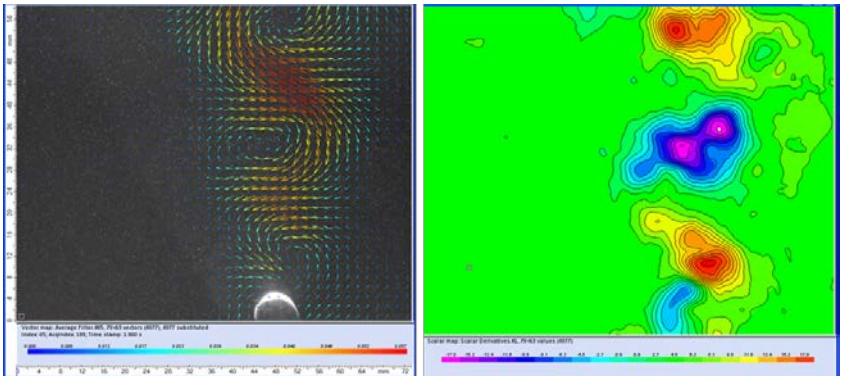
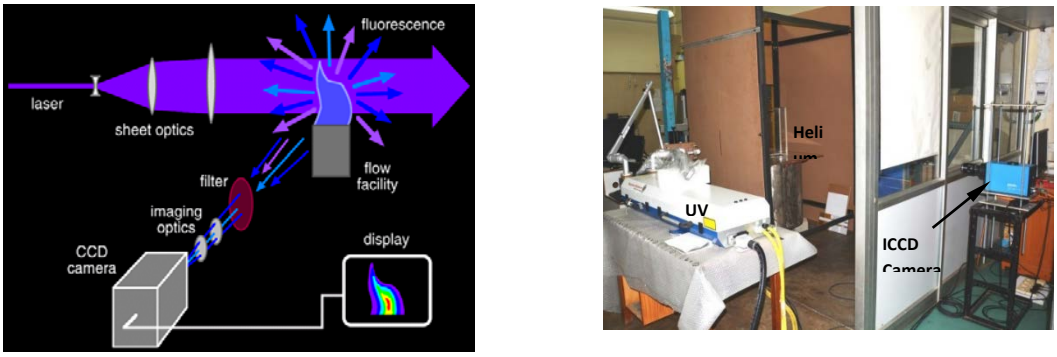


Figure: Velocity and vorticity fields in the wake of a circular cylinder.

- **In-house development of Planar Laser Induced Fluorescence (PLIF) technique for species concentration measurements in fluid flows**

PLIF is a non-intrusive, instantaneous measurement technique predominantly used to determine concentration of various species over a plane in non-reacting and reacting fluid flows, combustion, fires etc.



(a) Basic PLIF arrangement (Taken from Introduction to PLIF, R K Hanson) (b) Laboratory set-up for PLIF on Helium plume developed with K. K. Bharadwaj (Ph D Student)

In unsteady aerodynamics lab, this technique is developed for measurement of helium concentration and mixing in a helium plume emanating into air. A pulsed UV laser was used to excite acetone vapour, which is used as a molecular tracer and the emitted pale blue fluorescence from acetone was captured using an Intensified CCD camera. A MATLAB image processing routine had been developed in the lab to process these fluorescence images into helium concentration by correcting for laser sheet non-uniformities and using images taken for known concentrations as reference. A typical raw fluorescence image and corresponding helium mass fraction field thus obatined are shown here.

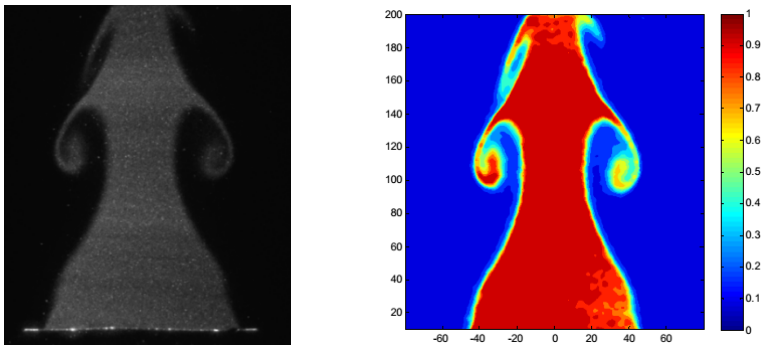


Figure: A typical raw fluorescence image and corresponding helium mass fraction field

Sponsored Project:

Period	Sponsoring Organization	Title of Project
2019-20	ADA	Wind Tunnel Model Design, Fabrication And Testing Of A Flying Wing Configuration(Co-PI)
2019-20	OFB	Feasibility Study And Preparation Of Dpr For Smart Shell System
2019-21	ARDB	Development And Assessment Of Hybrid Rans/Les Models For Predicting Flow Physics In An Airfoil With Leading Edge Tubercles (Co-PI)
2019-20	CARITAS INFRA CON. PVT. LTD.	Wind Tunnel Model Study Of Siarang Section Of Nf Railway In Mizoram(Co-PI)
2017-20	DST	Experimental Investigations Of Instabilities In Newtonian And Viscoelastic Fluid Flow Through Deformable Tubes (Co-PI)
2017-20	DAE-BARC	Development Of Background Oriented Schlieren (Bos) Technique For Density Measurment And Visualization In Buoyant Plumers
2014-19	BOEING	Active Flow Control High Lift Study- Year 1-5 (Co-PI)
2012-14	DAE-BARC	Development of a low cost PIV system
2012-14	DAE-BARC	Experimental investigation of turbulent buoyant plume & ceiling jet behavior using time resolved PIV (TRPIV), shadowgraph and quantitative Schlieren
2011-2014	NPMICAV (DRDO)	Design, construction and aerodynamic testing of bio-mimicking flapping wing micro air vehicles and models
2014-16	IITKanpur	Design and fabrication of an autonomous flapping wing unmanned air vehicle for surveillance and aerial photography
2011-14	BOEING (USA)	High lift aerodynamics project- Phase 1-5 (Five projects)
2011-2013	ISRO	Starting flow characteristics of s200 solid motor in ground test conditions: near and far field acoustics and near field velocity measurements

2009-2011	ISRO	Development of Schlieren system to study the shock structure during starting of GSLV MK-III
2008-09 2009-10 (2nd phase)	AFRL, AOARD, USA	Aerodynamics Characteristics Of Butterfly Flight Through Measurement Of Three-dimensional Unsteady Velocity field Using TRPIV System
2008-2010	ISRO	Measurement Of 3-D Unsteady Velocity Field Of Impinging Transient Jet
2007-2009	ISRO	Experimental Investigation Of Flow And Noise Characteristics Of Impinging Transient Supersonic Jets for Simulating Take Off of a Rocket Booster From Launch Pad
2007-2009.	AR&DB	Experimental Investigation Of Aerodynamics Characteristic Of Bird Size Flapping wings And Development Of An Ornithopter
2005-2007	ISRO	Experimental investigation of the characteristics of exhaust flow field and noise field from a pulsed detonation tube:cold study