

Research focus

- At Biomedical design lab, we are interested in modelling various Human organs.
- Understanding that physiology forms the basis of biomedical design and even clinical practice.
- Patient specific models are the basis for next generation medicine.

Research Areas

- Advanced Modelling of Diabetes
- Non-invasive measurement of portal pressure using ultrasound
- Brain shift prediction using FEA and imaging techniques
- Percutaneous Left Ventricular Assist Device (LVAD)
- Wave Propagation in human arterial tree
- Modelling of Human heart
- Brain tumor segmentation – Deep learning

Research Outcomes

- Automated Diabetic Retinopathy Software – Patent filed
- Automated Framework For Fetal Biometry From 2D Ultrasound Images - (Translational research)

Portal Pressure Measurement

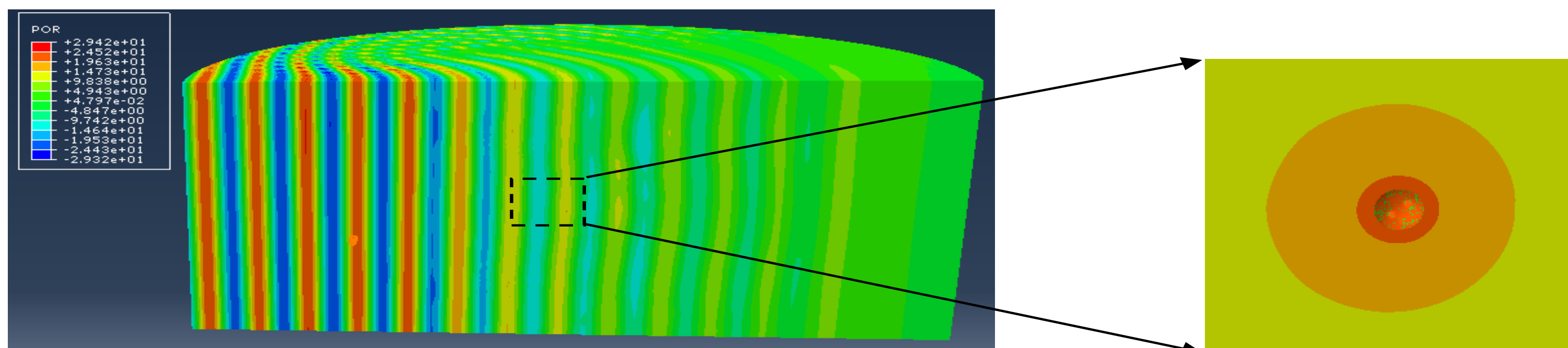


Fig. 1 (a) Acoustic pressure profile from portal vein with microbubble at the centre

Fig. 1 (b) Magnified view of microbubble Response

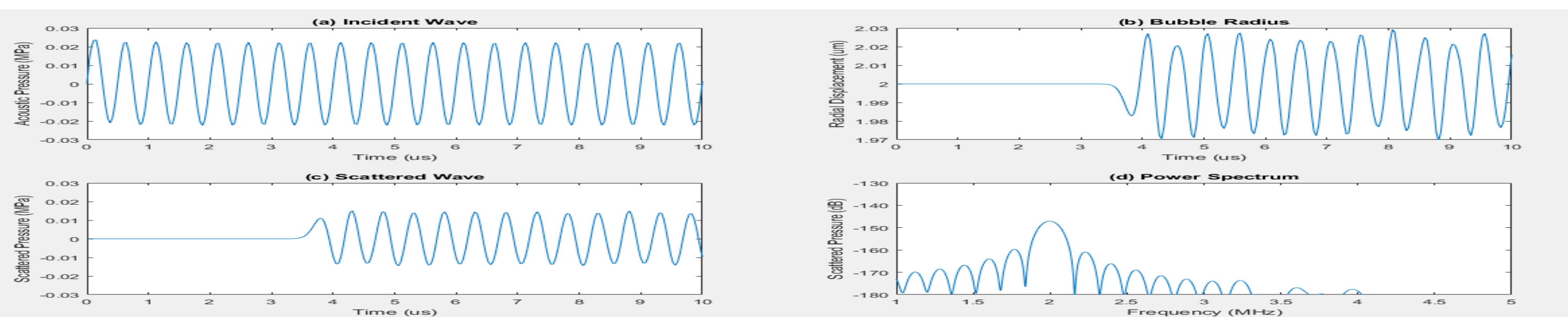


Fig. The response of microbubble in the portal vein, Acoustic excitation with 2 MHz frequency

Diabetes Model – Virtual Patient

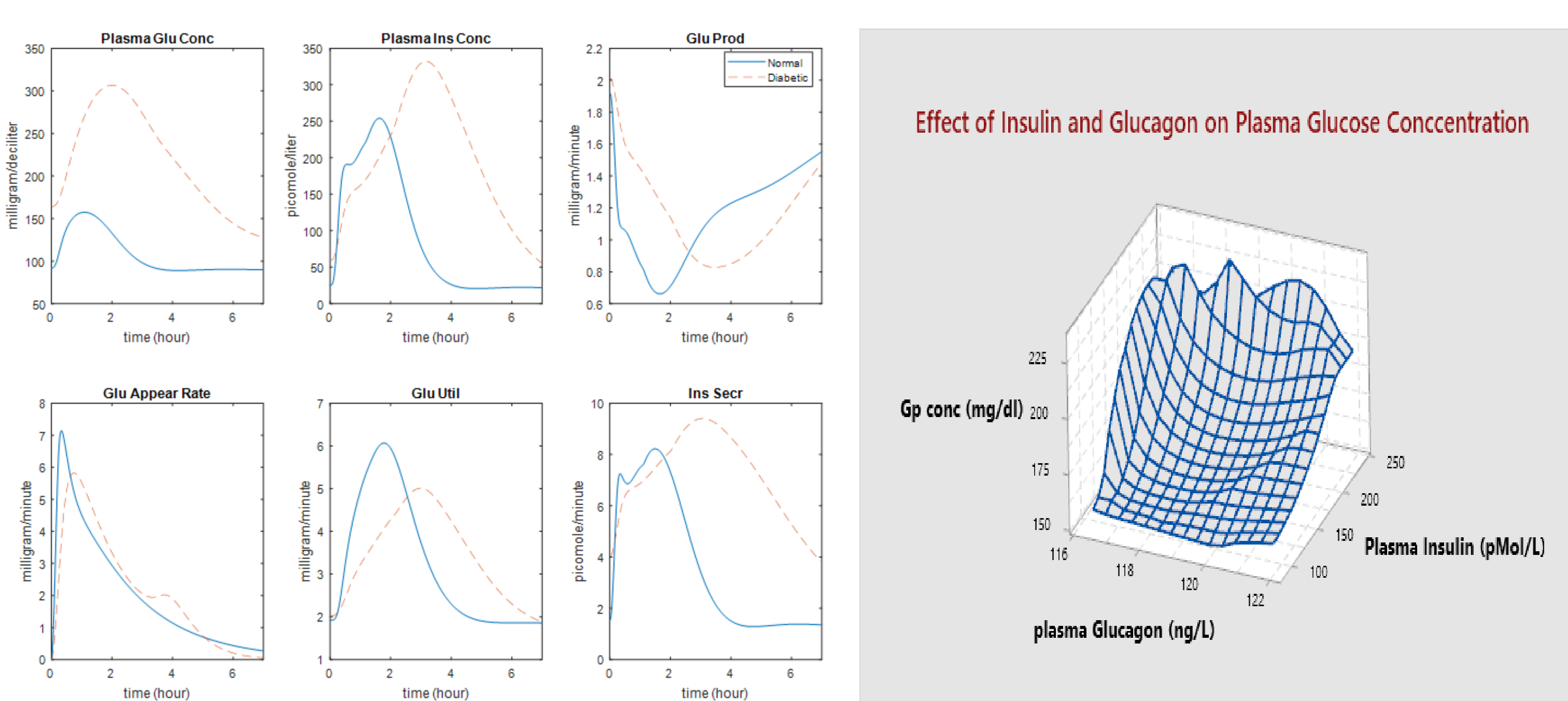
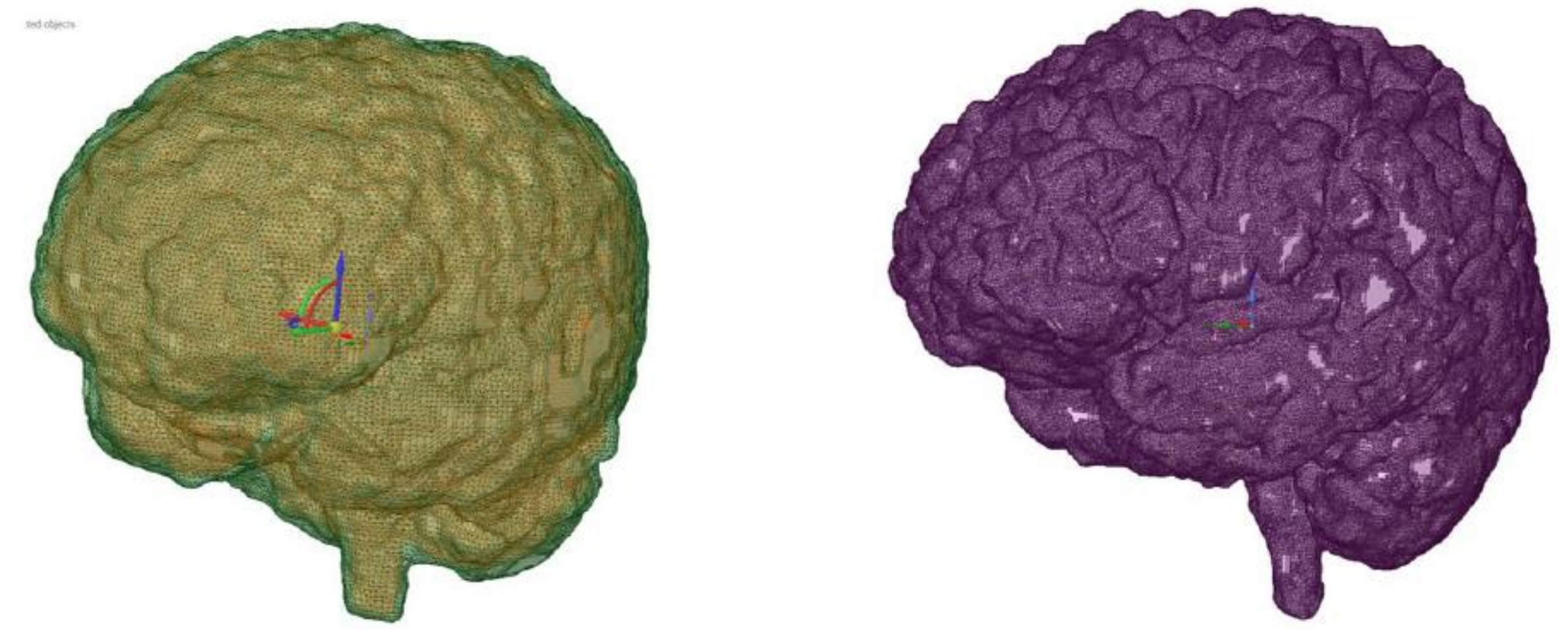
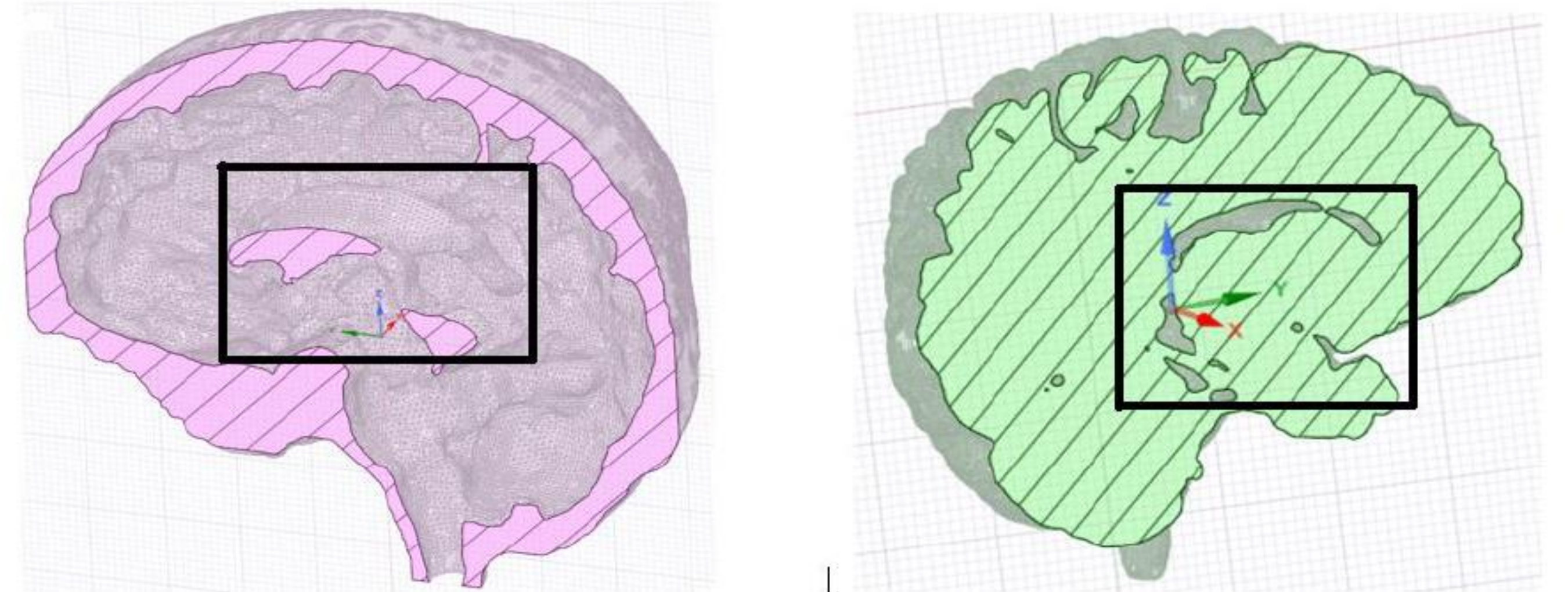


Fig. Model prediction of glucose, insulin and glucagon kinetics followed by a mixed meal or oral glucose dose.

Brain Shift Predictions - Image Guided Surgery



Cerebrospinal fluid pathway is in dark green, brain structures in brown and a 3-Dimensional model of brain structures without csf pathway.



cross-sectional view of Cerebrospinal fluid flow regions and Brain structures (from left to right) with ventricular spaces

Brain Tumor Segmentation – Deep Learning

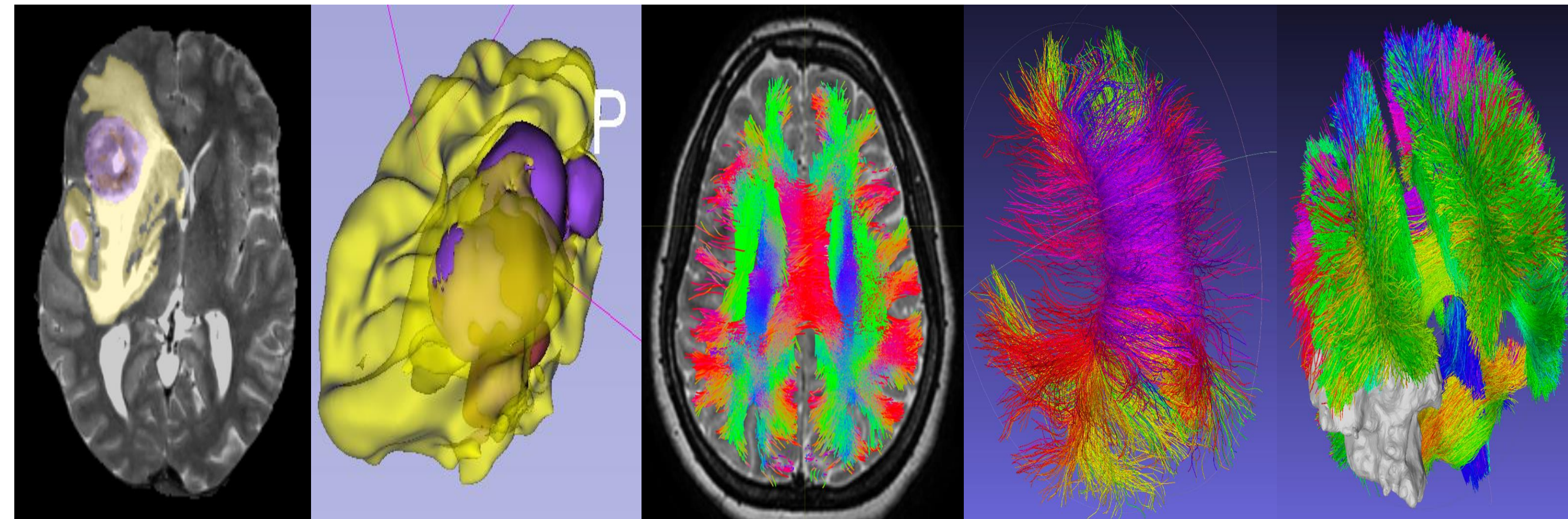


Fig. 3D Segmentation of Brain tumor and tractography using Deep learning

Percutaneous LVAD

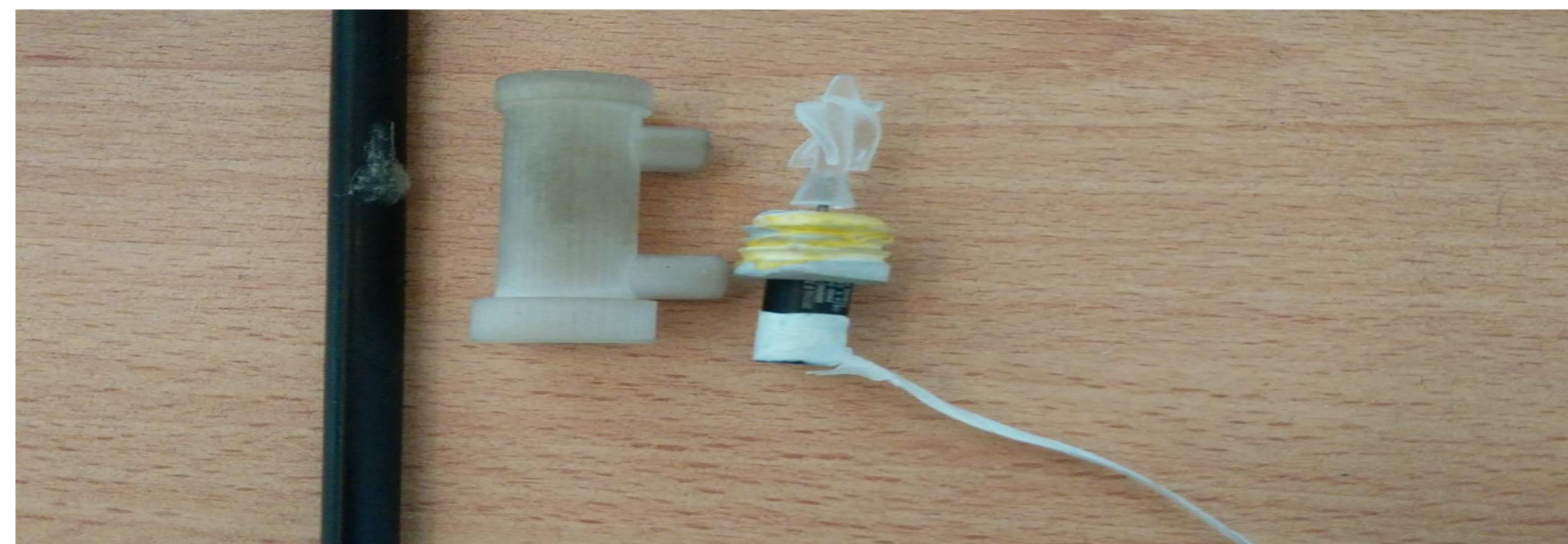


Fig. The image shows an inhouse developed pavad of diameter 8mm and length 12mm attached to a micro bldc motor , on left the image shows a pump casing developed to test the pump performance in laboratory. The pencil is just to give the physical micro limit that we reached. The pump is capable to pump 2.5 l/min at 60 mm of hg pressure.



Fig. Particle image velocimetry on systemic mock circulation loop
 The image shows a systemic mock circulation loop which is used to test an inhouse developed percutaneous type left ventricular assist device, on which piv is being done to test the flow field.

Optical Coherence Tomography (OCT) Technique for Biomedical Applications

Optical Coherence Tomography (OCT) is an optical imaging technique which enables non-invasive, non-ionising, real-time and high resolution imaging in micrometer order of various tissues. OCT records intensity of back-scattered light from various layers inside the tissue up to a depth of 1 to 2 mm. It works on the principle of low-coherence interferometry. OCT is currently being used in imaging retina, blood flow, **dental decay**, atherosclerosis, gastroenterology, dermatology etc.

Different approaches:

(i) Time-Domain Optical Coherence Tomography (TD-OCT) and (ii) Frequency-Domain Optical Coherence Tomography (FD-OCT)

Current research work is focused on:

- i) Development of an **electro-optically tuned** optical coherence tomography (OCT) system for imaging dental lesions
- ii) Near infrared (1.3, 1.6 and 2.1 μm) based **differential absorption OCT** system for glucose sensing

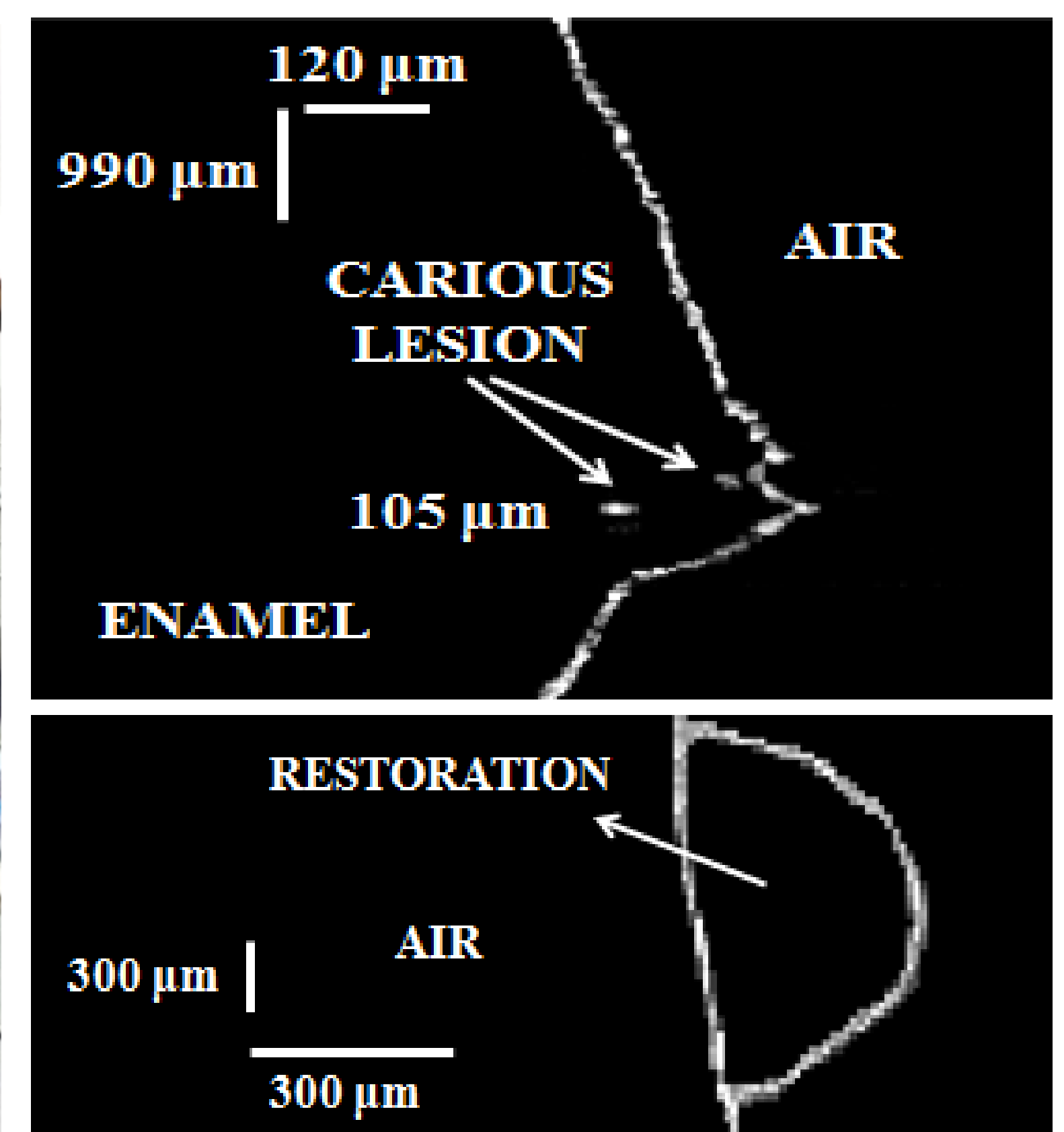
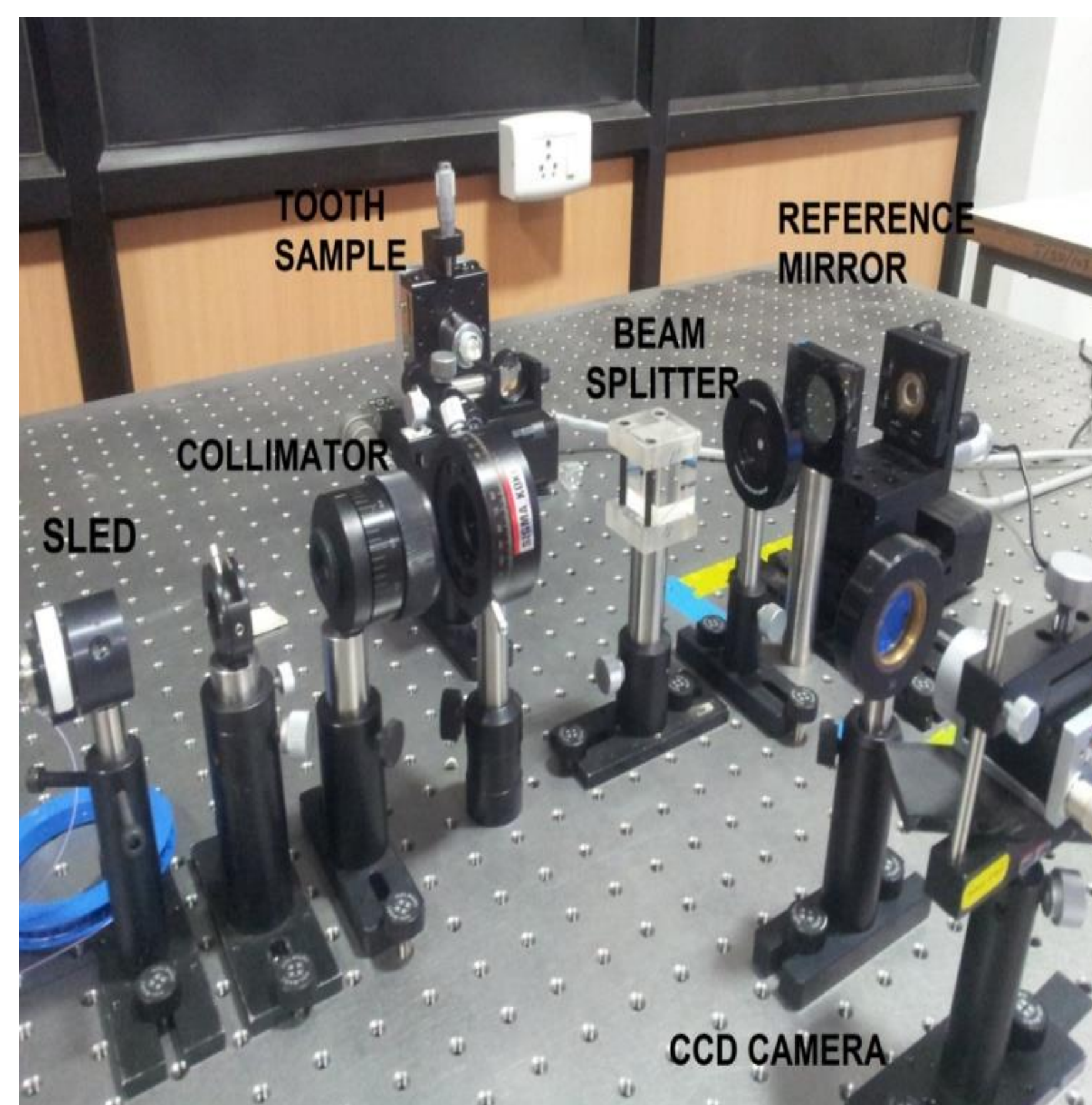
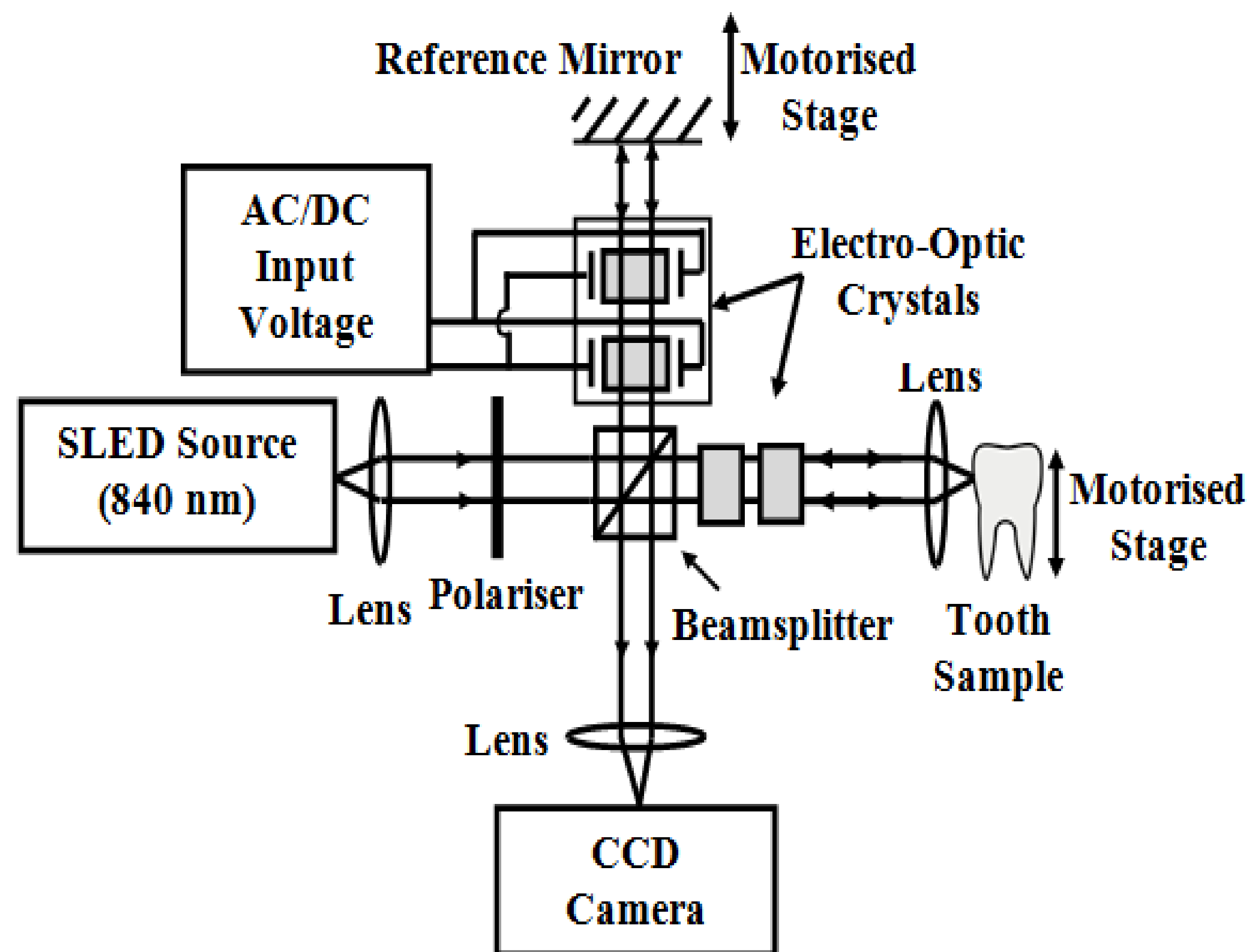
Project: DST (2014-2016)

Research Team: Vani Damodaran, Pauline John, Kathari Karunakar, N. J. Vasa (ED)

Collaborators: R. Sarathi (EE), N. Sujatha (AM), Dr. Suresh Rao (Dental Surgeon), S. Somasundaram (PHY)

Electro-Optic Tuning: Dental OCT @ 840 and 1300 nm

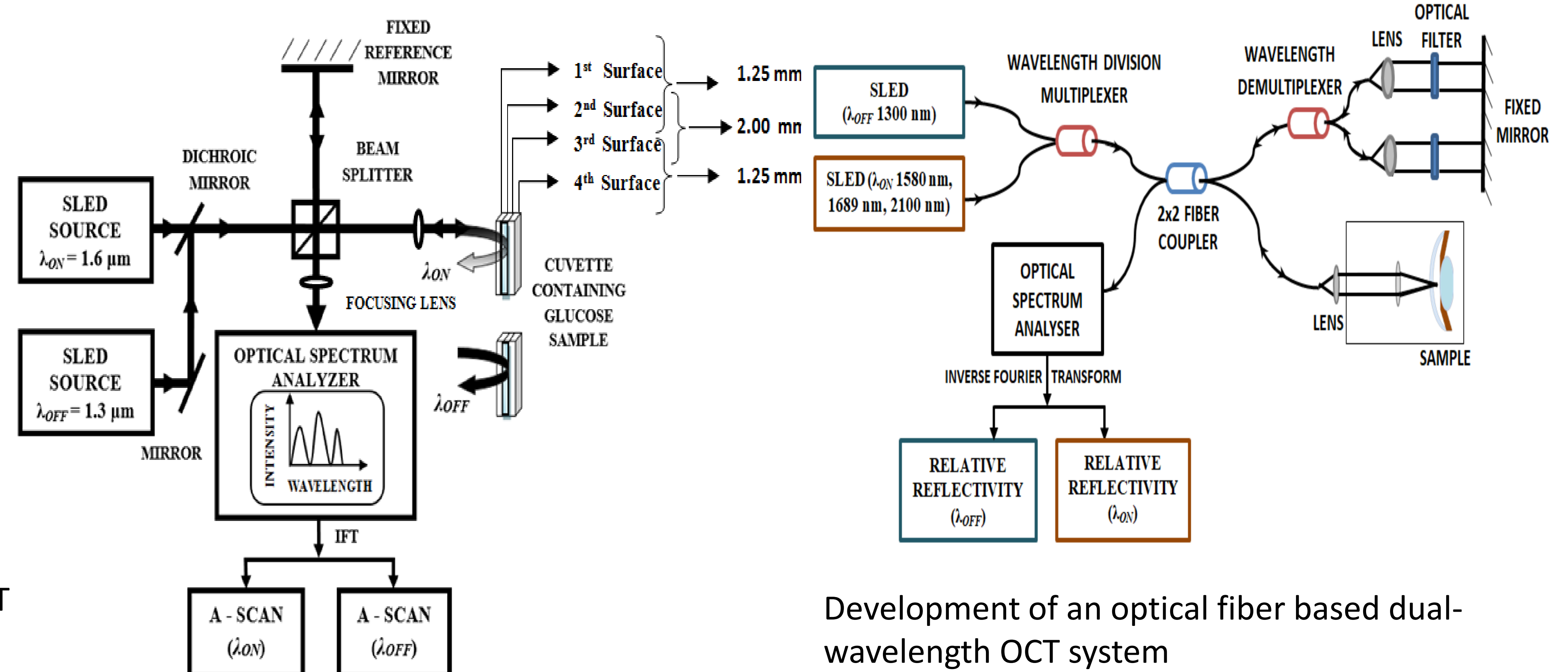
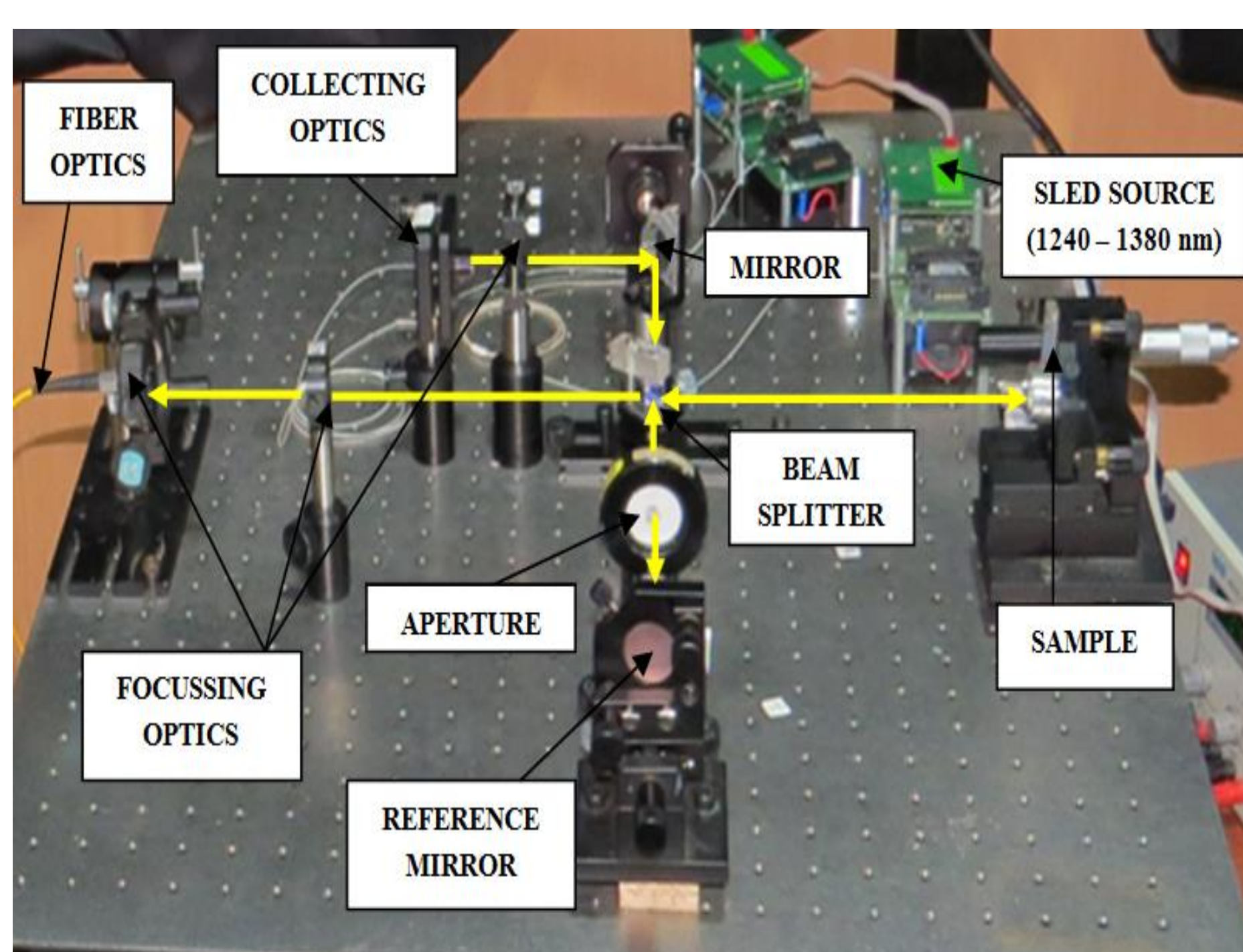
- (i) Development of an electro-optic based high speed scanning mechanism for time domain OCT system for early caries imaging
- (ii) Electro-optic based high speed mechanism for polarization sensitive OCT system for contrast enhanced dental imaging



Imaging carious lesion, restoration and demineralization study

Dual-Wavelength Low Coherence Interferometry @ 1600/1300 and 2100/1300 nm

Glucose sensing in (i) ex-vivo human gingival tissue, (ii) Aqueous humor of the eye-model



Development of an optical fiber based dual-wavelength OCT system

Patents

- (i) Granted: A device and methods for determining the elemental identity and analysis on moving target from a variable stand-off distance, Indian patent No. 314839 (Application No.: 4578/CHE/2013, dated 9/10/2013)
- (ii) Applied: Quadratic electro-optic based deflection-free wide path-length modulation and lateral scanning device fro time domain optical coherence tomography (Application No. 201641026337 dated 2/8/2016)
- (iii) Off Resonant Broadband absorption based photoacoustic sensor for multiple gas sensing (Application no: 201941019317 dated 15/5/2019)

Research Focus

- Development of patient specific spine models for biomechanics study and implant design.
- Computer aided diagnosis for spine pathology using medical images

Research Areas

- Analysis of biomechanics of spine for the insertion of Pedical screws
 - Design of patient specific Hip bone implant and cervical implants
- Biomedical image analysis of spine pathologies like
- Modic change
 - Focal change
 - Metastases
 - Pott's spine
 - Consequences of deformity of spine like scoliosis

Important Outcomes

The patient specific implants helps to optimize the material stiffness in the implant for better load transfer characteristics.

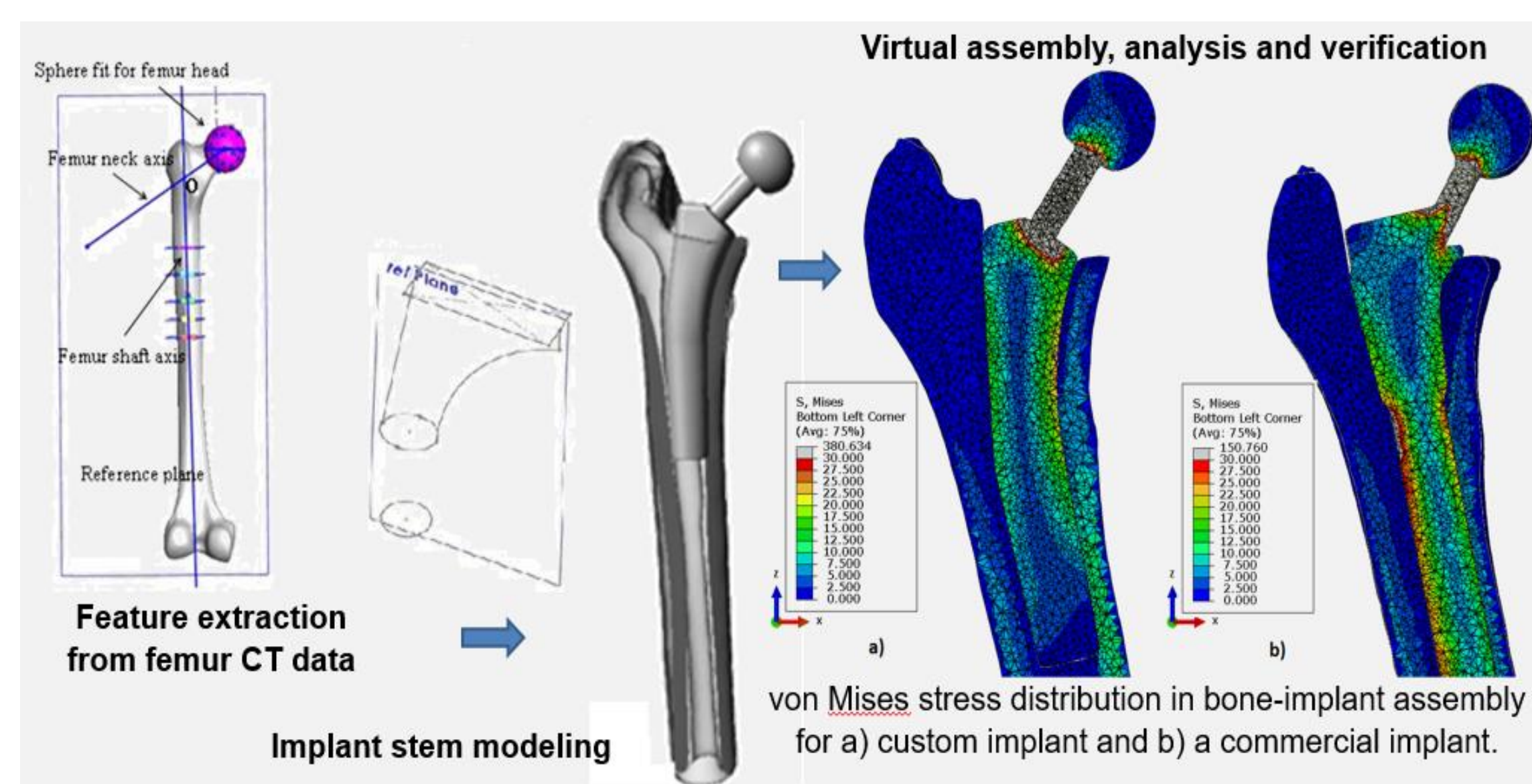
Computer Aided diagnosis of pathologies of spine helps the radiologists by reducing the screening time. This also eliminates the inter-rater error and gives consistency and reproducibility of the diagnostic reports.

Collaborators

- Prof. K. Venkatesh Spinal Disorders Unit, CMC Vellore, India
- Prof. Vedantam Rajshekhar Neurology Unit, CMC Vellore, India
- Prof. Satya Subramani Physiology, CMC Vellore, India
- Prof. Narayan Yoganandan Medical College of Wisconsin USA
- Dr. Jayaraj Govindaraj Radiology, Apollo Hospitals Chennai, India
- Dr. Harvinder Singh Chhabra Indian Spinal Injuries Centre New Delhi, India

Design and Analysis of Cement-less Hip Implant

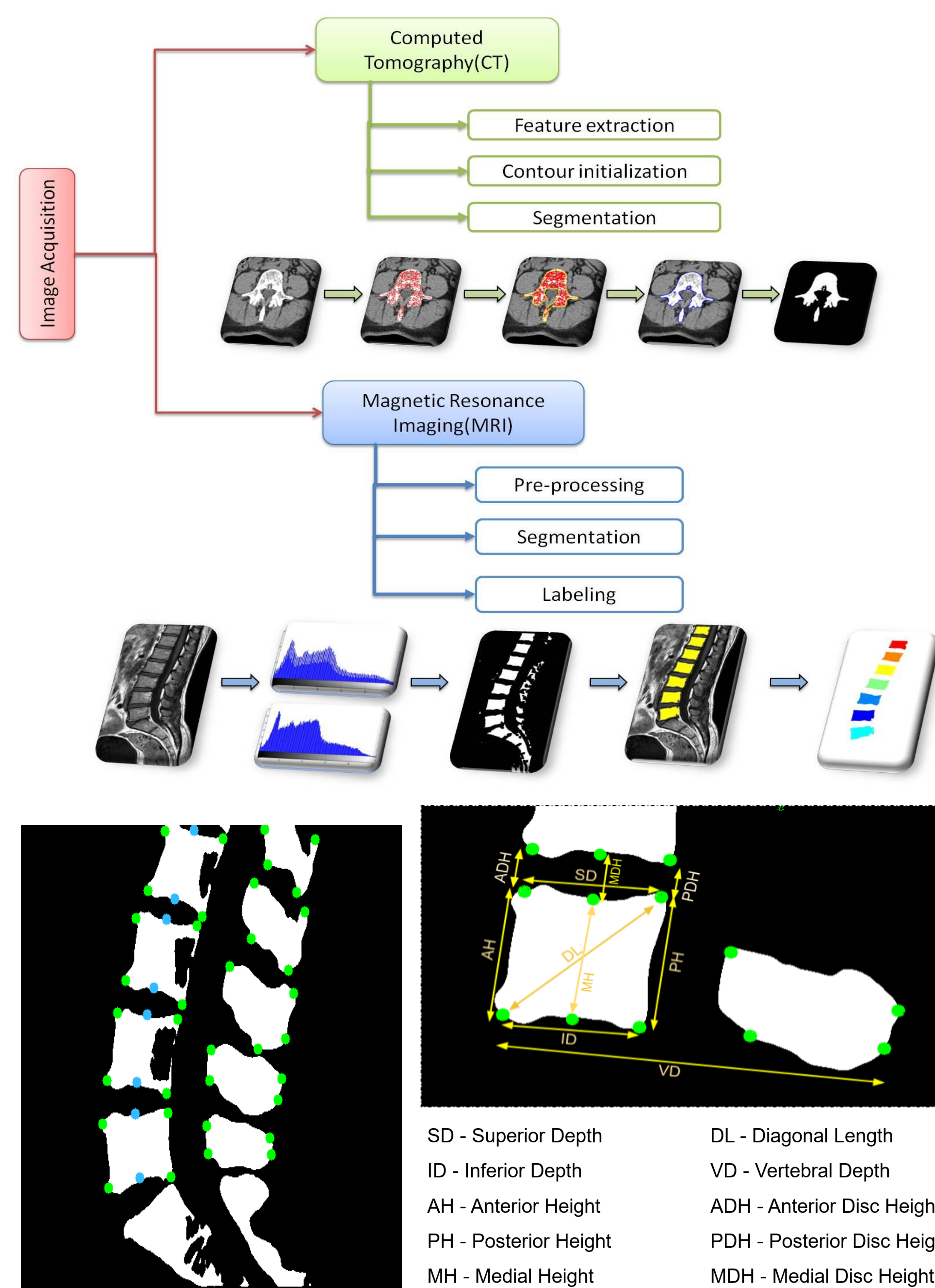
A set of pre-specified femoral features that can be used for custom implant design have been identified and extracted from the femur geometry reconstructed from computed tomography images. A parametric implant design is proposed based on the extracted femur features. Virtual assembly of the instantiated stem with femur model is done to check for the form fit. A finite element analysis of the resected femur with implant assembly is done for a known experimental loading condition to assess change in the stress-strain state of the femur and the stress shielding effect due to insertion of the implant. A commercially used modular implant design is chosen for the comparison studies in terms of form fit as well as stress shielding effect. The study shows that the proposed custom implant fares well in both these aspects.



George, S.P. and Saravana Kumar, G., *Patient specific parametric geometric modelling and finite element analysis of cementless hip prosthesis*, Virtual and Physical Prototyping, 8(1), 2013, pp. 65 – 83.

Imaging Studies on Spine

This study involves computer assisted diagnosis for Modic changes and Focal changes which leads to identification of disc degeneration and abnormalities.



JS Athertya, GS Kumar, *Automatic segmentation of vertebral contours from CT images using fuzzy corners*, Computers in biology and medicine, 2016

Pullout Strength of Pedicle Screws

Objective of this study is to develop a biomechanical model of vertebra for determining the holding power of pedicle screws under physiological loading. It attempted to understand

- The changes in biomechanics of the spine induced due to spine fusion
- The effect of biomechanical factors such as
 - bone density,
 - insertion angle,
 - insertion depth
 - reinsertion on pullout strength of pedicle screws

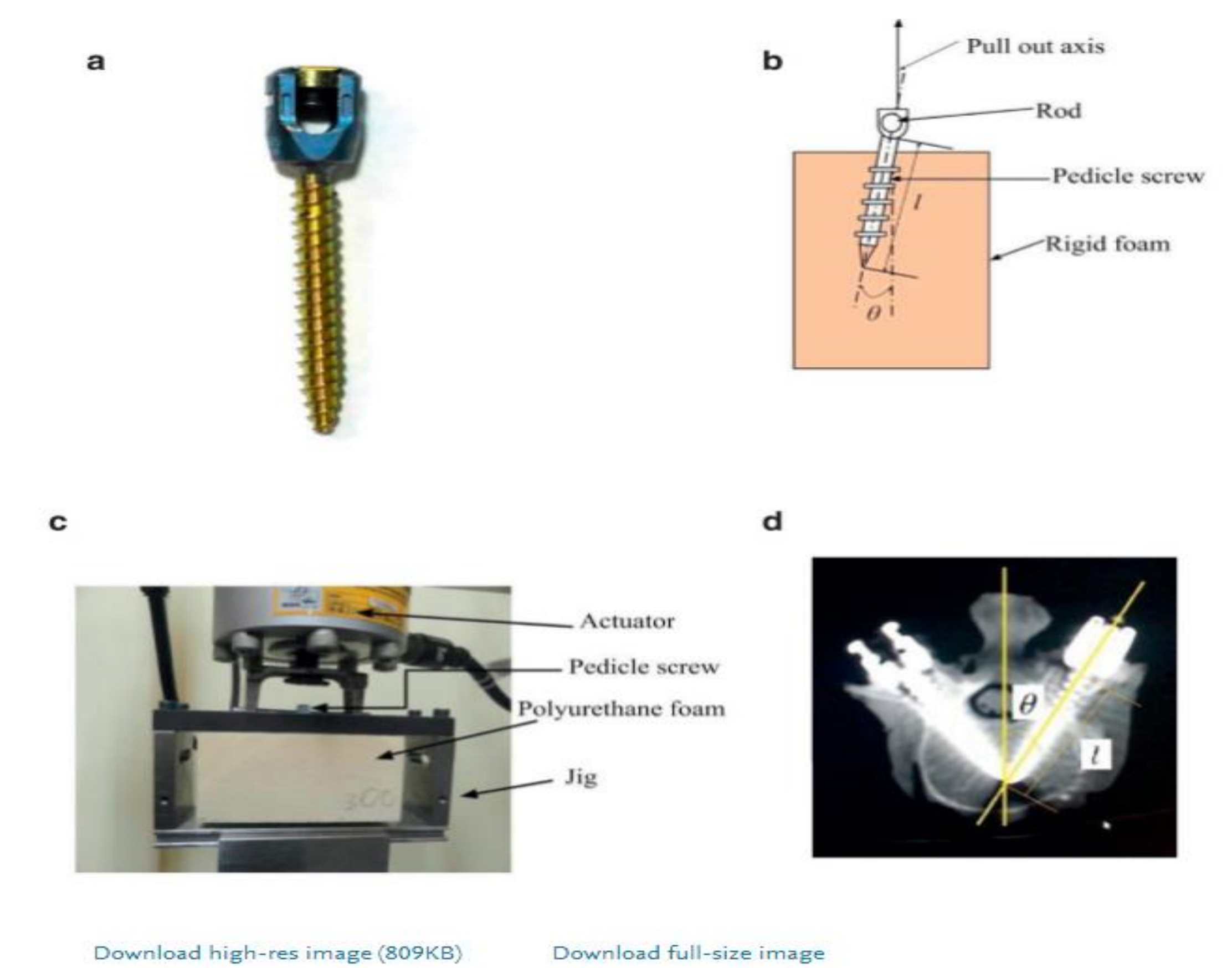
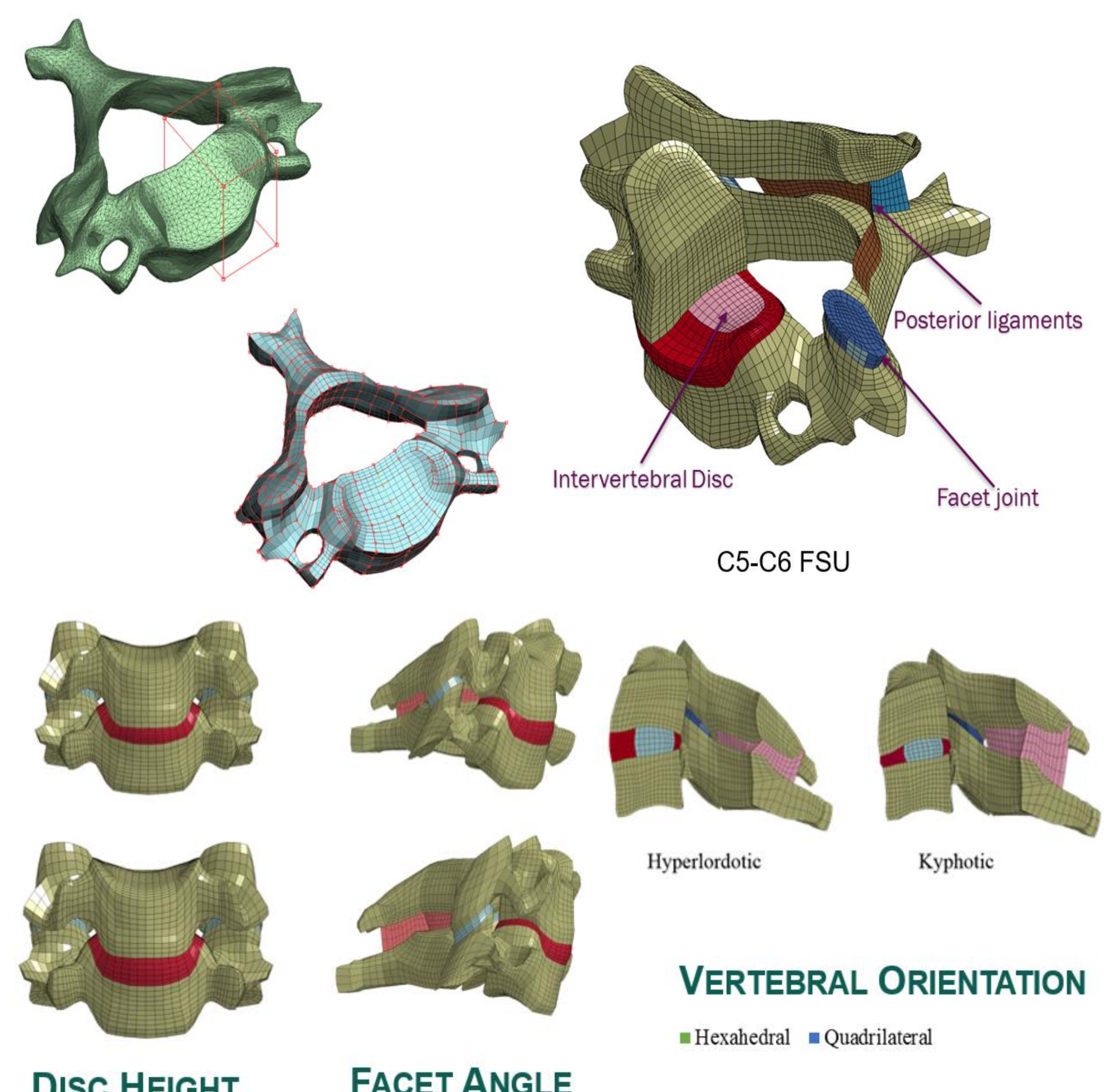


Fig. 1. (a) Polyaxial cylindrical Globus pedicle screw (Ø 6.5 x 45 mm); (b) Schematic representation of instrumentation; (c) Experimental set up for screw pull out; (d) Anatomy of pedicle screw instrumentation.

V Varghese, GS Kumar, V Krishnan, *Effect of various factors on pull out strength of pedicle screw in normal and osteoporotic cancellous bone models*, Medical engineering & physics, 2017

Subject-Specific Cervical Spine FE Models

A mapping-block based morphing technique was developed to parametrize the complex geometry of vertebral structure. This modeling approach is being used to investigate the influence of morphological variations on segmental rotation.



DISC HEIGHT

FACET ANGLE

John, Jobin D., Mike W. J. Arun, Narayan Yoganandan, Saravana Kumar, G. *Mapping Block-Based Morphing for Subject-Specific Spine Finite Element Models*. Rocky Mountain Bioengineering Symposium, March 30-31, 2017 Denver, Colorado.

Research focus

We at RBG Labs, IIT Madras focus on various disruptive innovation in developing medical devices, materials, implants that improves the care given and the cost of care delivery. Our biomedical research have been in disciplines such as human factors, physiological monitoring systems, design and development of devices and implants in cardiac, vascular, orthopaedic, dental, etc.

Finite Element Modelling and Analysis in thoraco-lumbar spine is carried out in injury analysis

Human factor research in psychological distress measurement, mind wandering on high cognitive loads during driving, electrophysiological response during mindless reading and neuro marketing.

The biomedical projects from our lab are aimed towards developing products that have great usability features and can bridge as enablers to increase human capabilities and reduce limitations.

Research Areas

- Medical Devices & Implants
- Human Factors in Transportation
- Design Thinking
- Technology Management and Public Policy

Summary

In medical devices and implants RBG Labs has developed Nstomoz clamp device, Xenogenic material for cardiac application, a novel dental composite by matrix and filler modifications. Studies on spine modelling and cognitive human factors can be evolved as an outcome to advice in framing public policies and commercialization of products.

Important Outcomes

Nstomoz is a new clamp design that prevents blood flow, but keeps the tunica intima open so surgeons have enough working space to do the stitches

Won the Gandhian Young Technological Innovation (GYTI) Award

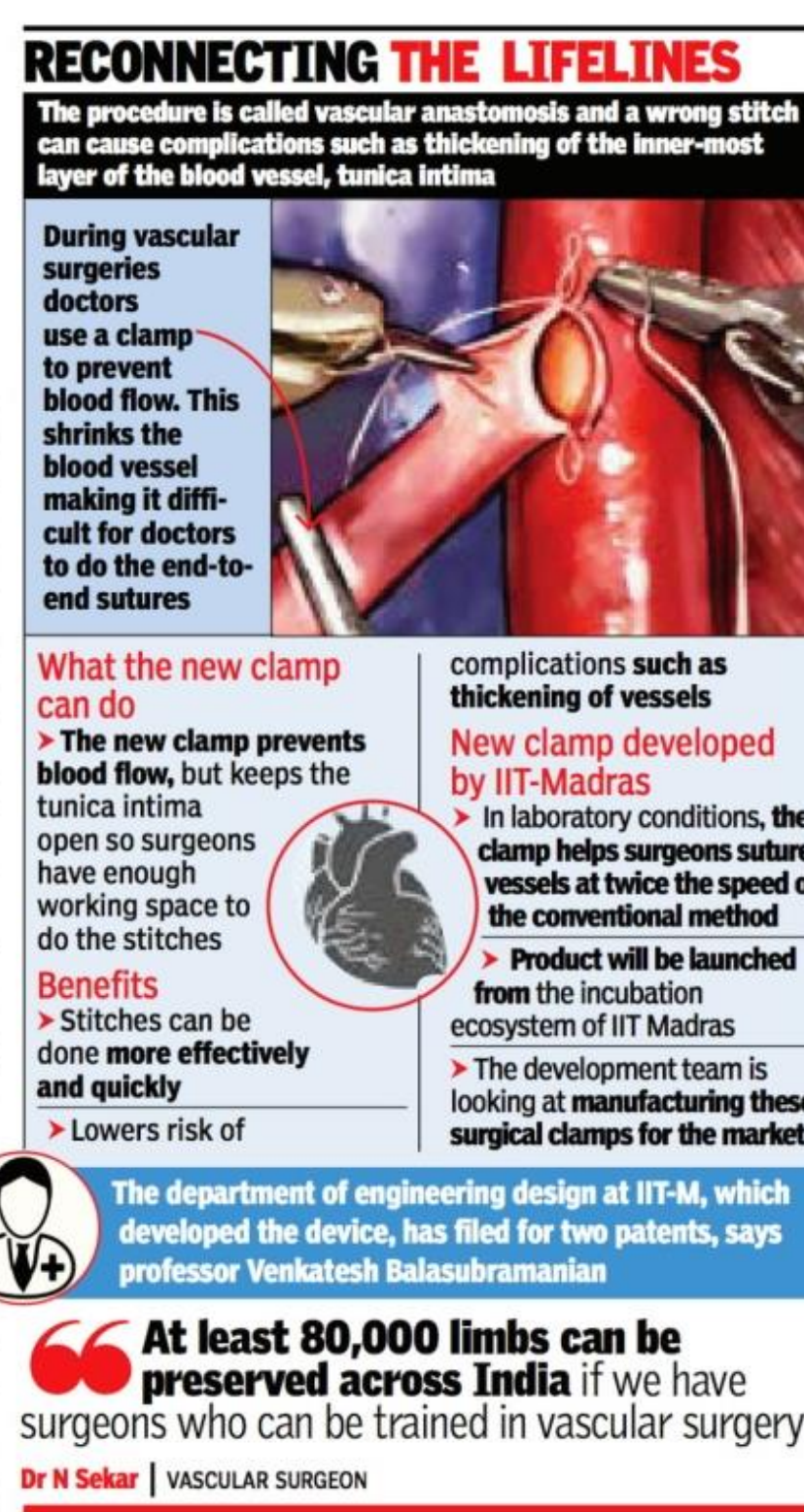
Technology Transferred to Shiva Med Tech from IIT Madras

Clamp from IIT-M to help fix blood vessels

Device Likely To Cut Cost, Complications

Pushpa.Narayan @timesgroup.com

A tiny clip-like instrument, not larger than a thumb nail, sits on the table of senior plastic surgeon Dr V B Narayanaswamy of Global Hospitals. As someone who operates on blood vessels, he is sure this eversion clamp, 'Nstomoz', will revolutionise the way people like him work besides reducing cost and complications of surgeries. Reconnecting blood vessels, a procedure called vascular anastomosis, is one of the most tricky jobs of a junior surgeon. Specialists, including in vascular, cardiovascular, plastic and transplant surgeons, master it through years of practice. A wrong stitch can cause complications such as thickening of the inner-most layer of the blood vessel, tunica intima. The process is so delicate that sometimes trauma patients' limbs are amputated because there are no specialists to suture blood vessels. "It's tough for beginners. Some are so disappointed with their skill levels that they stop



RECONNECTING THE LIFELINES
The procedure is called vascular anastomosis and a wrong stitch can cause complications such as thickening of the inner-most layer of the blood vessel, tunica intima

During vascular surgeries doctors use a clamp to prevent blood flow. This shrinks the blood vessel making it difficult for doctors to do the end-to-end sutures

What the new clamp can do
The new clamp prevents blood flow, but keeps the tunica intima open so surgeons have enough working space to do the stitches

Benefits
Stitches can be done more effectively and quickly
Lowers risk of complications such as thickening of vessels

New clamp developed by IIT-Madras
In laboratory conditions, the clamp helps surgeons suture vessels at twice the speed of the conventional method
Product will be launched from the incubation ecosystem of IIT Madras
The development team is looking at manufacturing these surgical clamps for the market

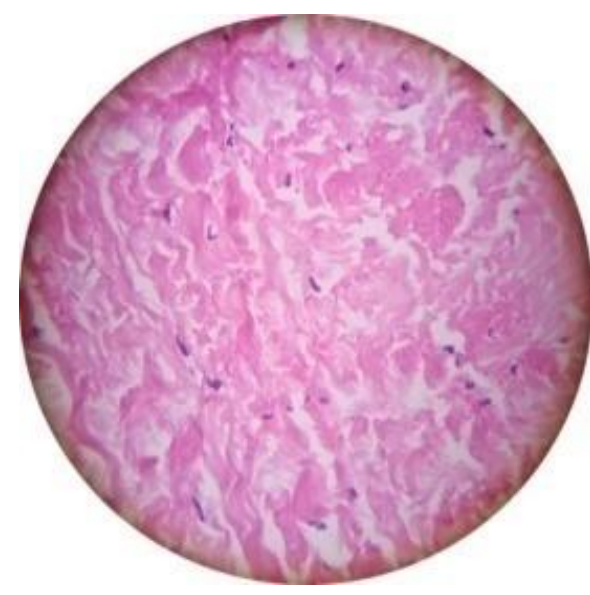
The department of engineering design at IIT-M, which developed the device, has filed for two patents, says professor Venkatesh Balasubramanian

At least 80,000 limbs can be preserved across India if we have surgeons who can be trained in vascular surgery

Dr N Sekar | VASCULAR SURGEON

Xenogenic Material for Cardiovascular Application

Technology Transferred to M/s SynkroMax to market the product as SynkroScaff, India's first Bioprosthetic Material



St. Jude Medical Pericardium \$120/sq in



Brazilian Pericardium \$50/sq in



IITM Pericardium \$1/sq in

Contact: Dr. Soma Guhathakurta Adjunct Professor Engineering Design, IIT Madras Director, Bio-engineering Division with SynkroMax Biotech Pvt. Ltd

Novel Dental Composites by Matrix and Filler Modifications formulated with high molar volume resin, very low number of reactive moieties and filler uncoupling

A new resin matrix and filler modification viable for clinical use with high DC, great stability, high biocompatibility and self-adhesive potential developed

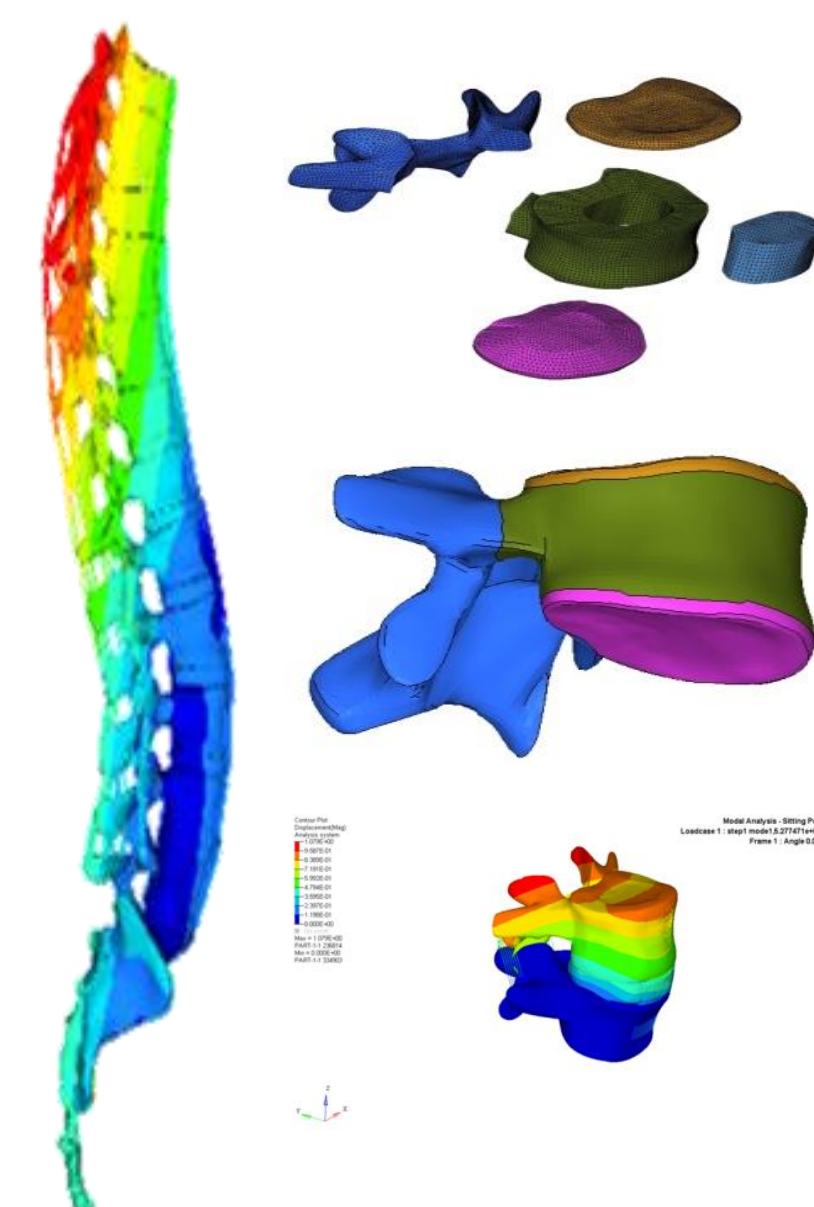
Patent obtained No: 2709/CHE/2013, June 2013

Contact: Dr.Susila Anand, Head of the Department of Conservative Dentistry and Endodontics, Madha Dental College & Hospital, Chennai

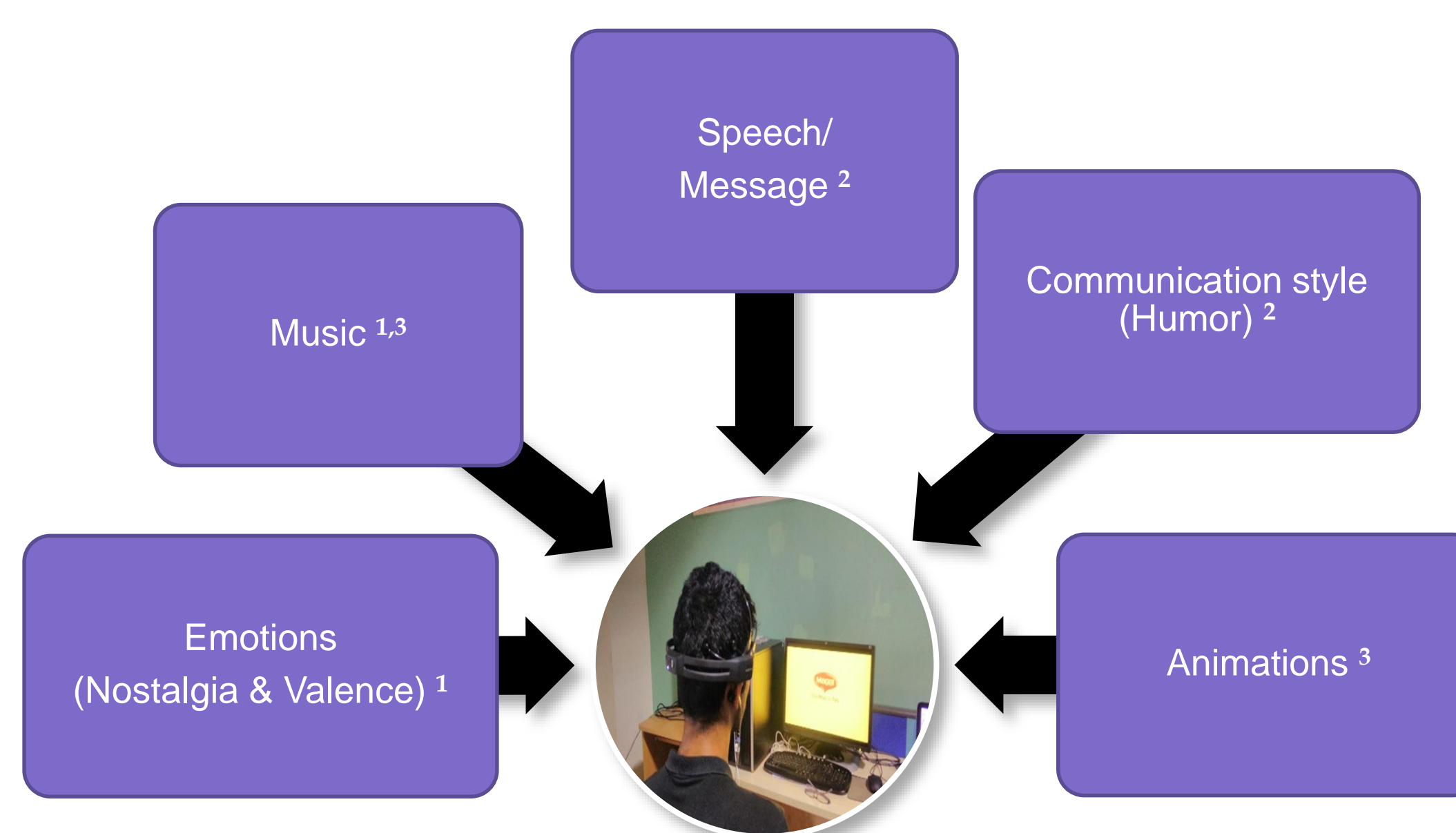
Hi-fidelity FEM of Thoraco-Lumbar Spine

Finite element method is applied to simulate the 3D bio-mechanical representation of spine and its fidelity for varying material property.

This model can be used to perform injury studies, biomechanical testing, clinical treatment and also for comparison between various human spine centric designs



Neuromarketing Studies @ RBG Labs



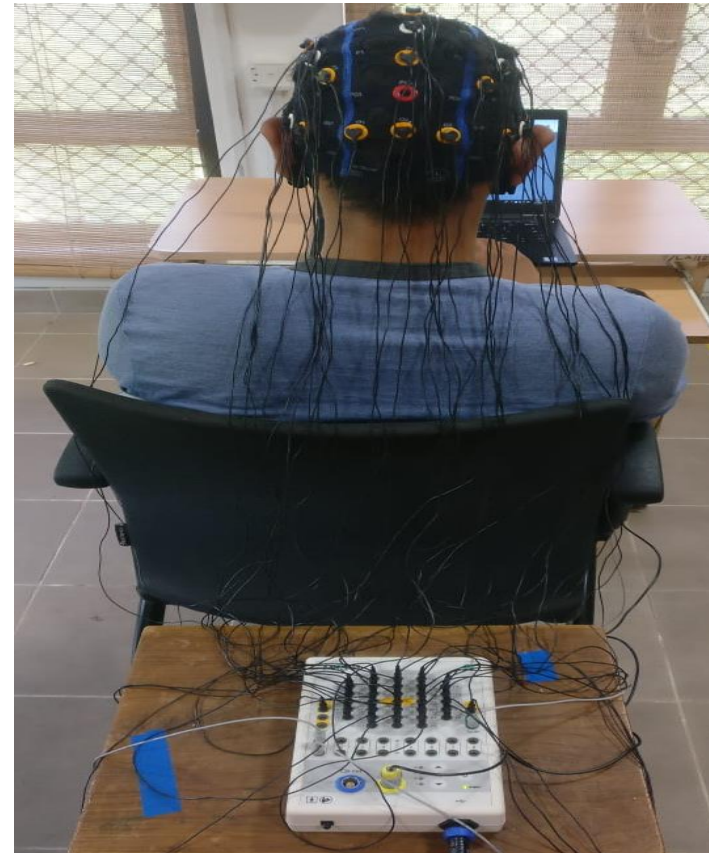
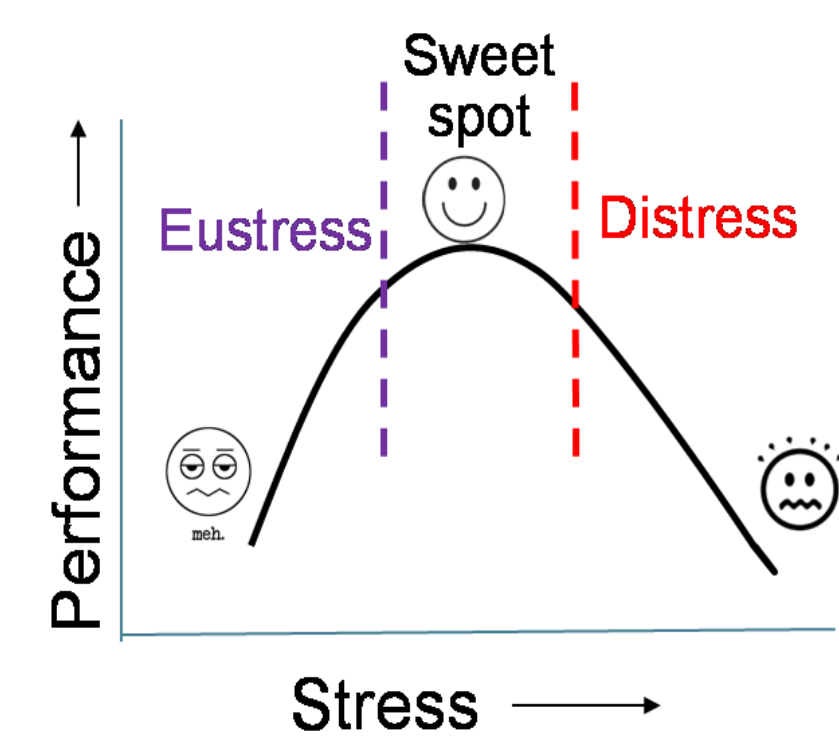
Behaviour Studies

¹Study on Impact of Maggi Noodle Ban on Sales

²EEG based evaluation of viewer's response towards TV commercials

³Product Human Factors Evaluation in TV Commercials Using Psychophysical Test

Psychological Distress in Students

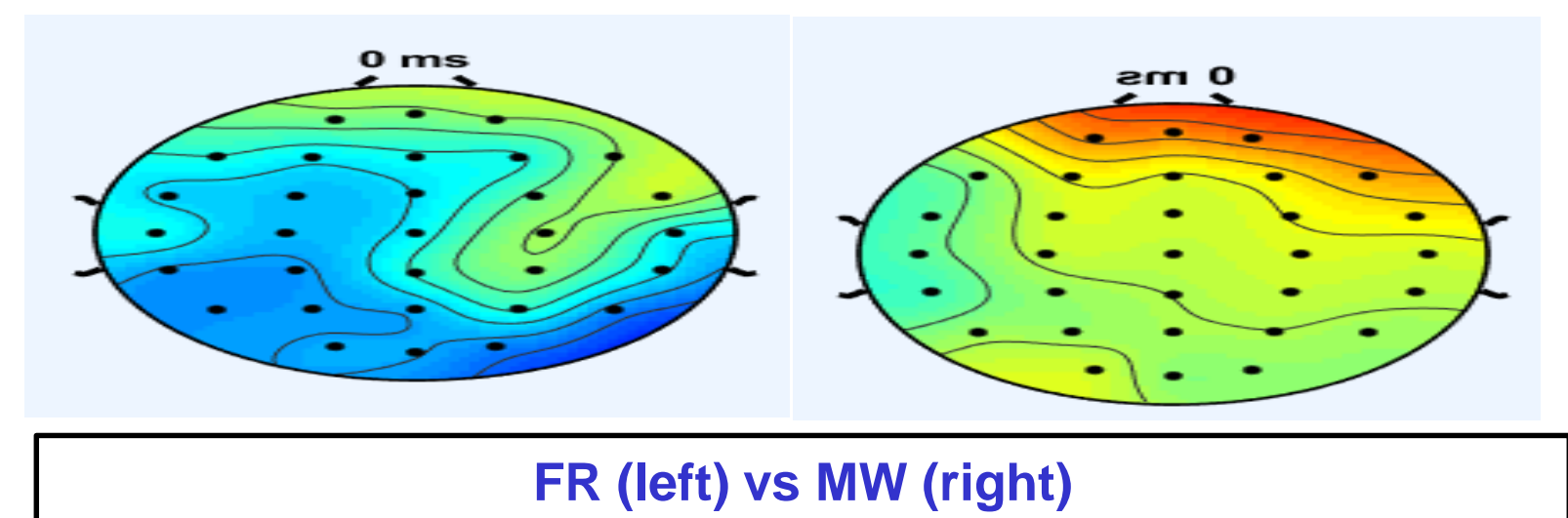


Measurement Techniques

1. Behavioral (Avoidance & Reaction time)
2. Subjective (Anxiety score (STAI) & Affect (PANAS))
3. Physiological (ECG & EEG)

Volunteer to the study and know more!!

Mind Wandering



Electrophysiological Response during Mindless Reading

Mindless Reading = Mind wandering while reading

Distribution of average scalp potentials during focused reading (FR – full attention on reading) and during mind wandering (WM) at 0ms (start of focused reading and mind wandering episodes)

Mind Wandering Frequency in High Perceptual Load Driving Environment

Personal Matters and Driving Environment are major contributors of mind wandering behind wheels

As speed increases:

- Utilization of attention resources increases, to maintain vehicle control
- Spared capacity decreases resulting in less mind wandering

Publications/ Sponsors

1. Shivashankar S, Dr. Venkatesh Balasubramanian (2014), Validation Methodology for High Fidelity Numerical Spine and its Ergonomics Aspects, International conference on Human Work and Working Environment (HWW), IIT Guwahati
2. Rajendran, M., & Balasubramanian, V. (2019, July). Impact of Mind Wandering on Driving. In International Conference on Applied Human Factors and Ergonomics (pp. 224-232). Springer, Cham
3. S.Guhathakurtha, V. Balasubramanian, B. Ananthkrishnan, S. Veerappan, R. Balasundari, B.V.R Tata, K.M. Cherian, Thrombogenicity studies of three different variants of processed bovine pericardium, ITBM-RBM, Vol 29, Issue 4, 223-230, 2008
4. V. Susila Anand, Venkatesh Balasubramanian. Effect of resin chemistry on the depth of cure and cytotoxicity of dental composites. Material Science and Engineering: Part B, 2014; 181:33-38. JIF: 1.8

Research focus

Our lab focuses on developing Bio NEMS/MEMS platforms for single cell technology. Over the years biological research have developed to explain fundamentals of life and their applications for better living. As the technology developed, cell heterogeneity and rare cells were detected highlighting importance of studying individual cell characteristics. Such analysis require micro/nano structures for manipulating individual cells and cell organelles. With micro/nano fabrication techniques different mechanisms could be developed.

Research Areas

- Single cell nano-electroporation - Bio NEMS chip for electroporation used to deliver non permeable cargo into cells
- Photoporation based intracellular /extracellular drug delivery
- Intracellular drug delivery through mechanoporation using microfluidic devices
- Micro-contact cell printing technologies
- Microfluidic neuronal platform for neuron regenerative studies
- Diamond-like nanocomposite thin films and its biomedical applications
- Nano/micro structuring on biomedical implants for drug delivery applications
- Transdermal microneedles patch for controlled and intracellular drug delivery applications.
- Neuronal development on carbon nanofiller reinforced nanofiber using microfluidic devices.
- Nanostructure reinforced polymer fibers for laser mediated photoporation of drug

Important Outcomes

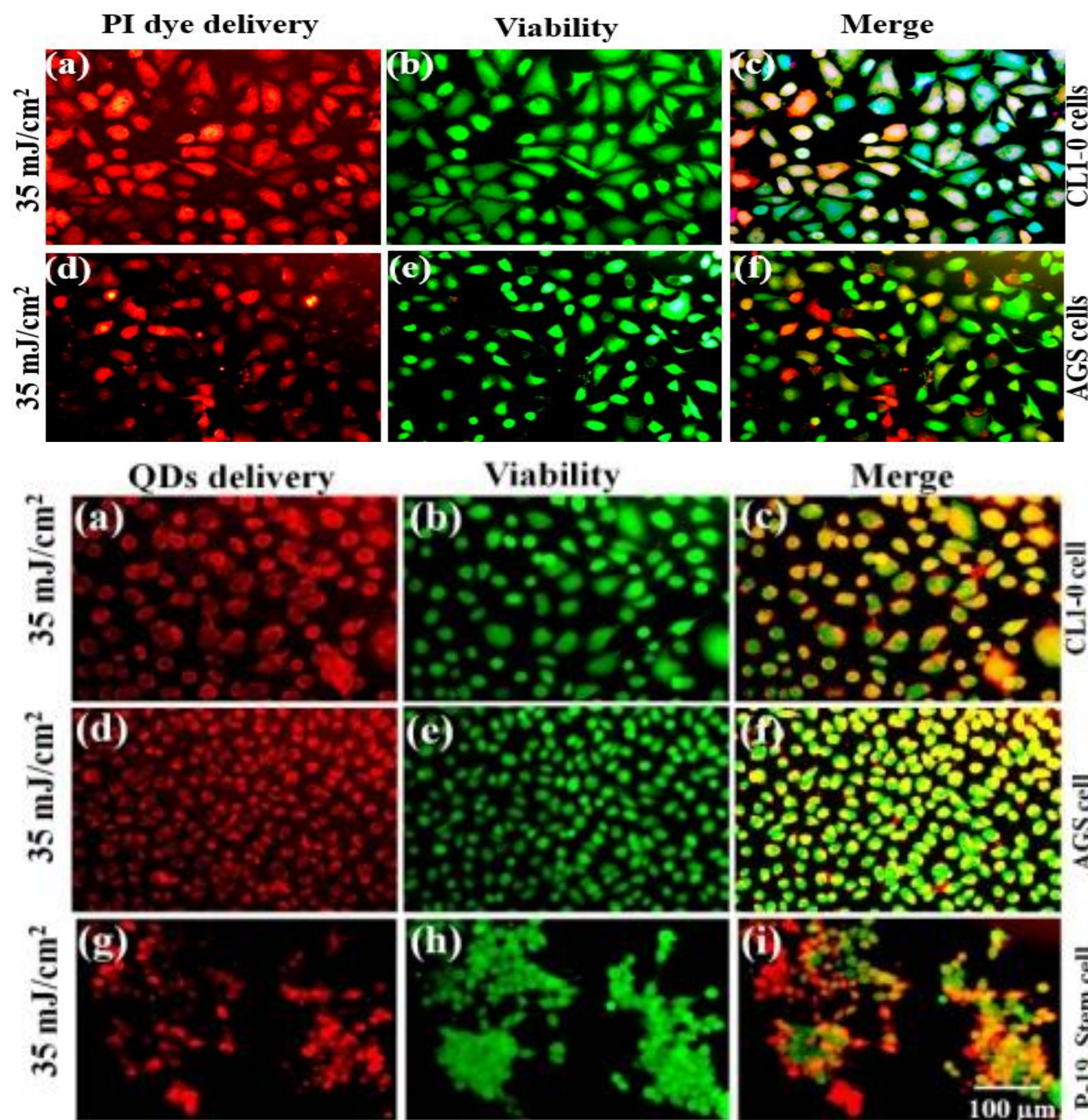
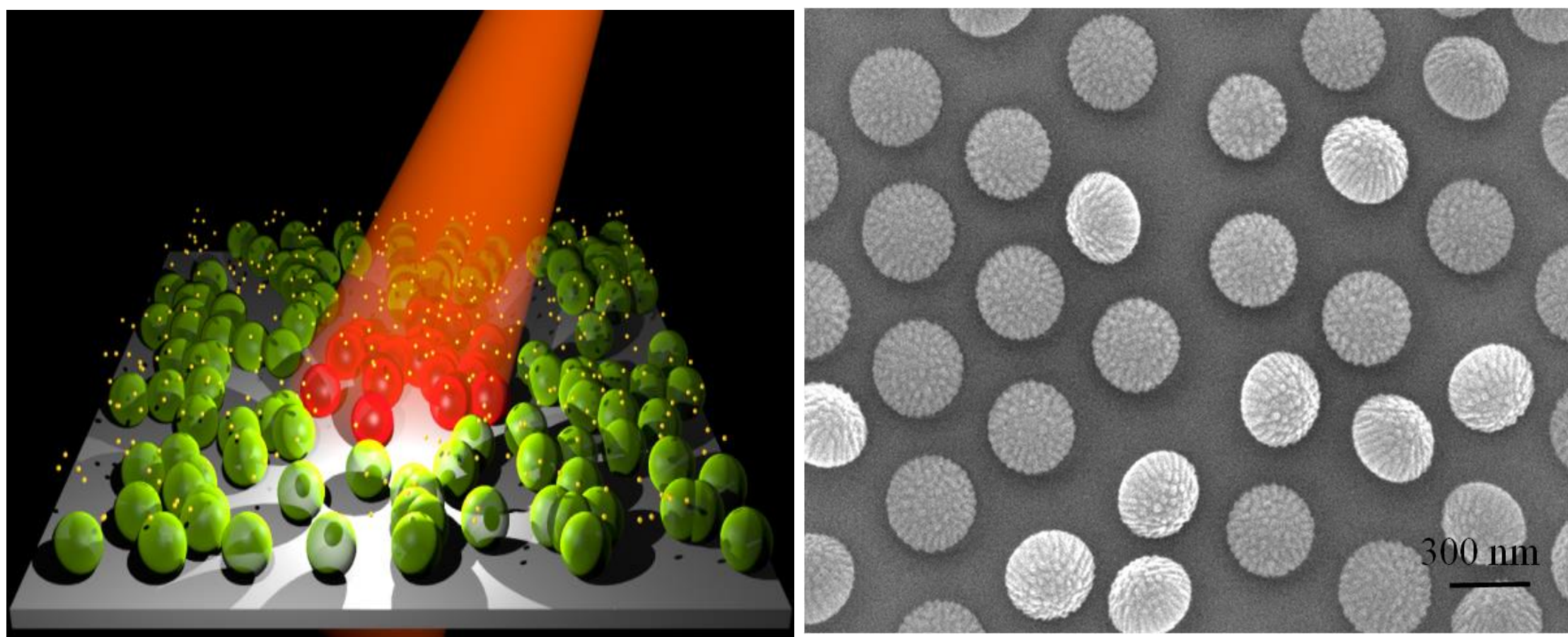
- Massively parallel uniform single-cell intracellular delivery can be achieved.
- Cell patterning to a resolution from few cells to single cell.
- Fabrication of Titania nanotubes (TNTs) for localized and sustained drug delivery.
- Fabrication of TNTs, Micro-spikes, flowers and cones for intracellular drug delivery.

Summary

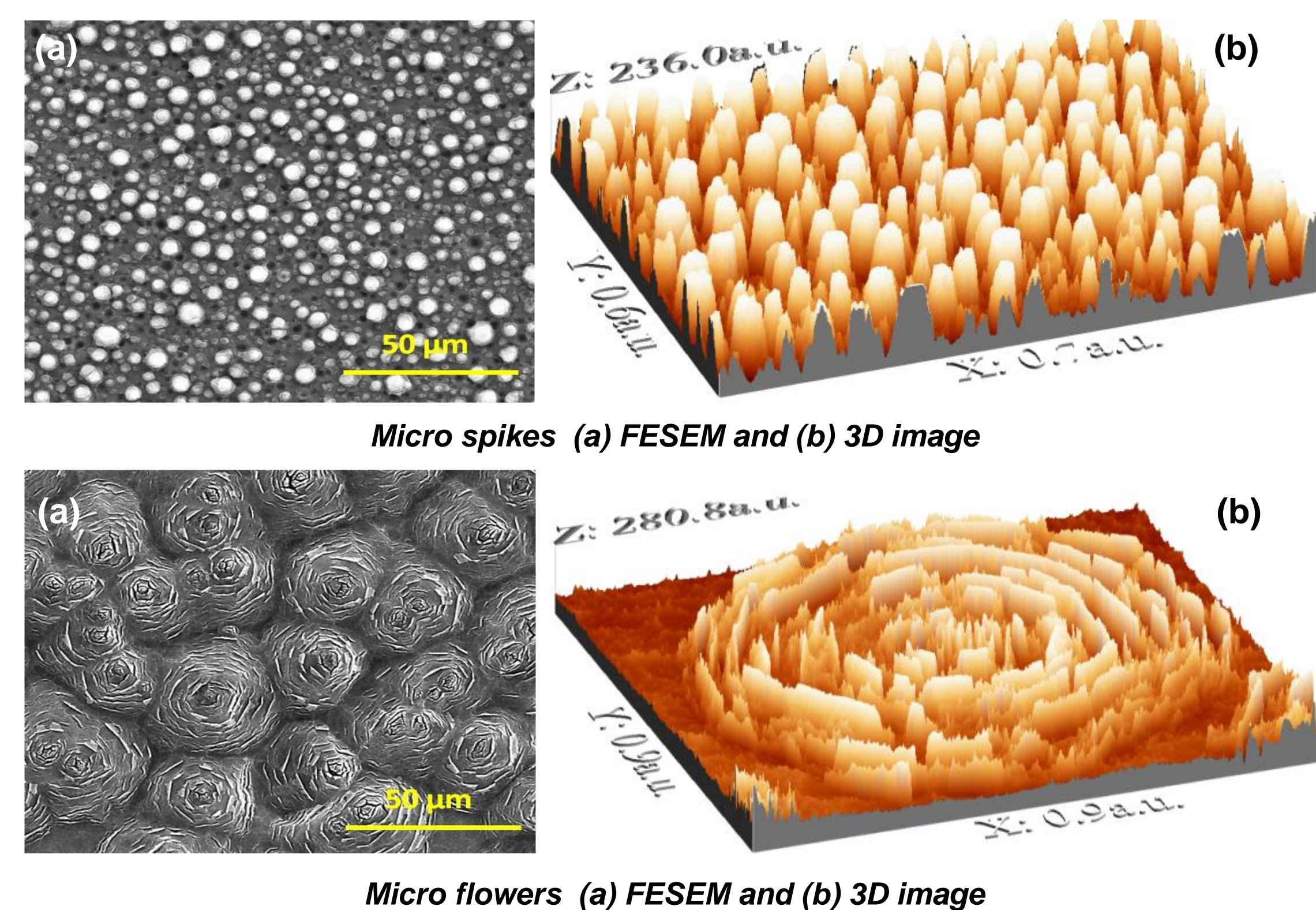
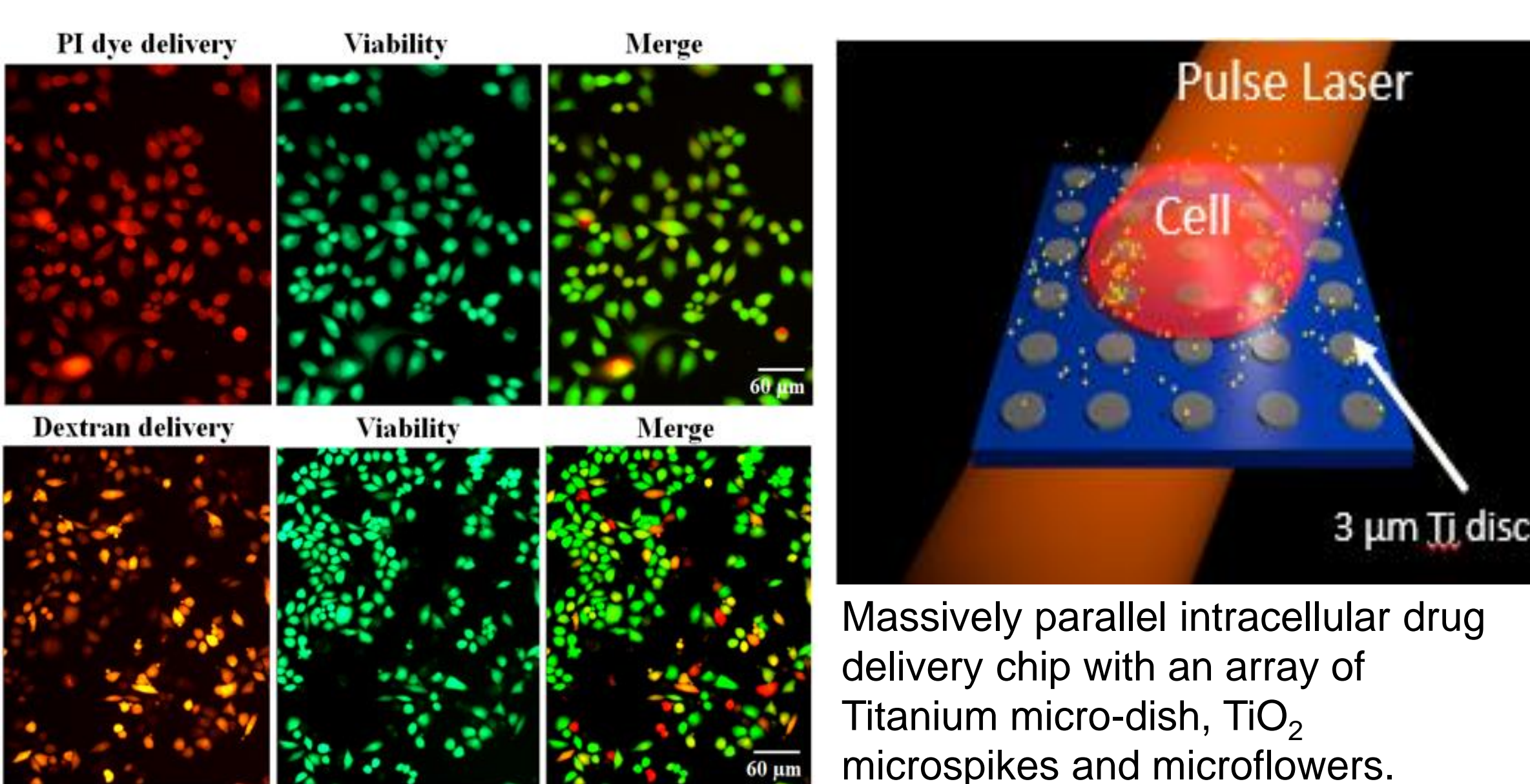
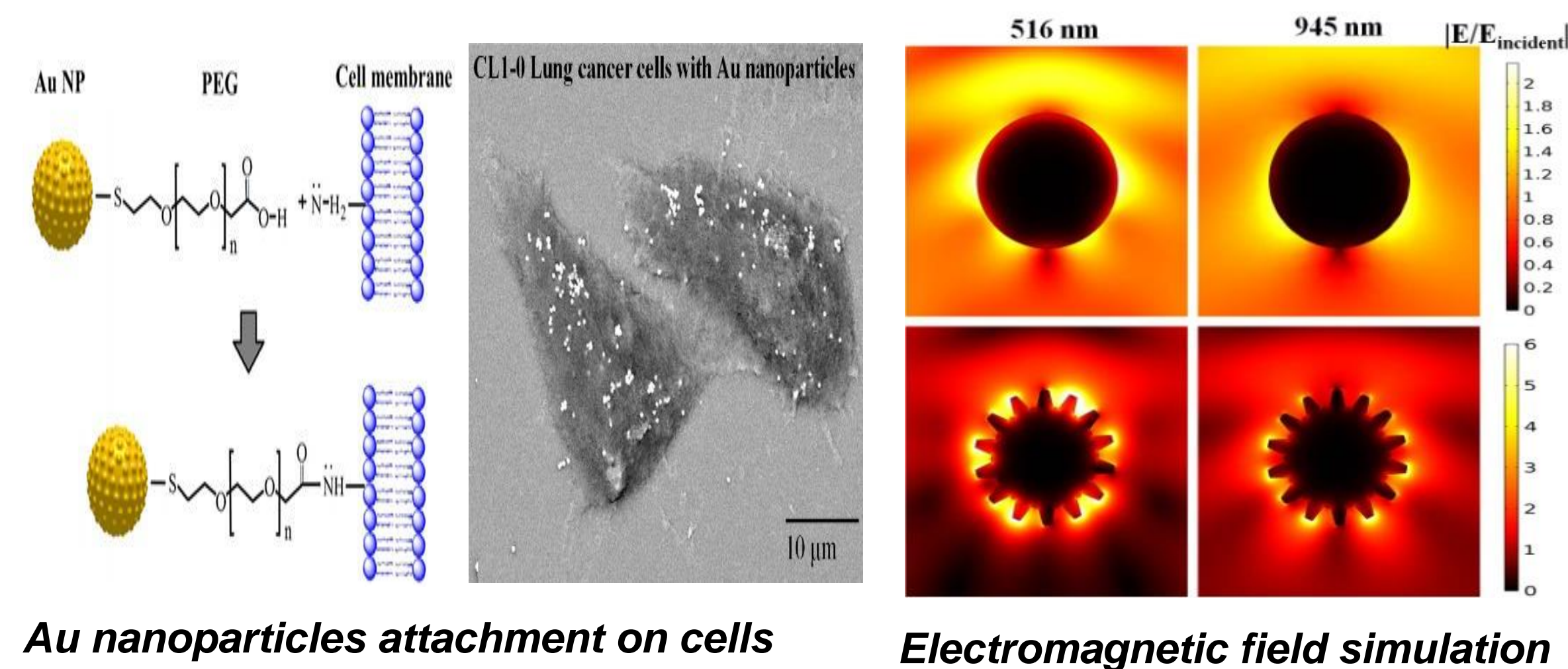
- To develop massively parallel single-cell intracellular delivery platform. This includes use of different forms of physical techniques for localize permeabilization of cell membrane.
- To develop feasible technique for substrate patterning and cell alignment. This can be useful in aligning cells according to *in-vivo* tissue structures and imitating them for understanding cell signaling in organs. Besides it can be useful in regenerative medicine and tissue engineering.
- To develop Lab-on-a-chip system for cell therapy and analysis.

Photoporation

Nano corrugated mushroom shaped nano particles used for intracellular drug delivery using Nano second pulsed laser

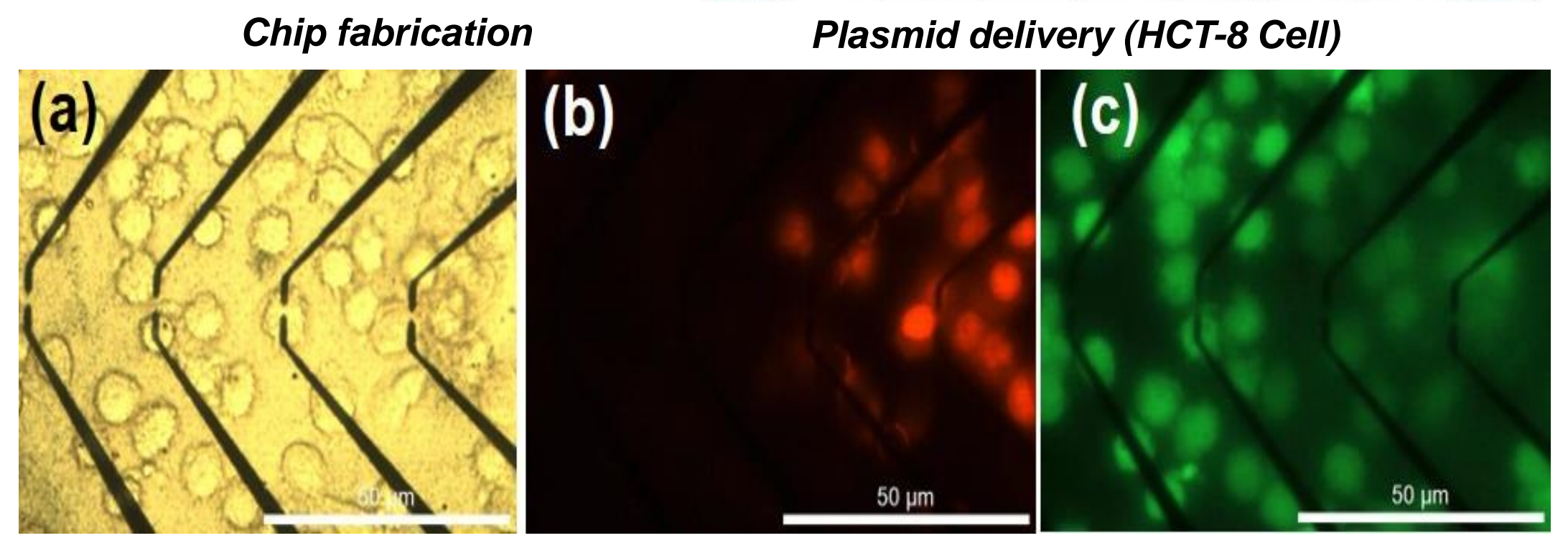
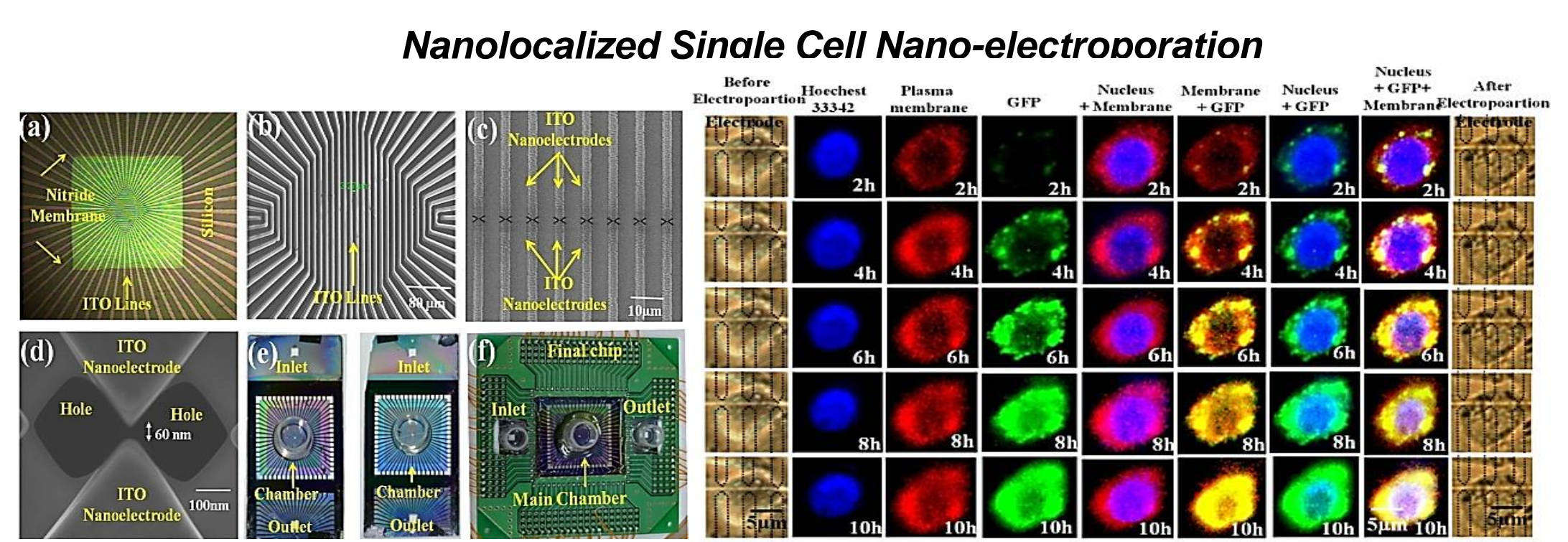
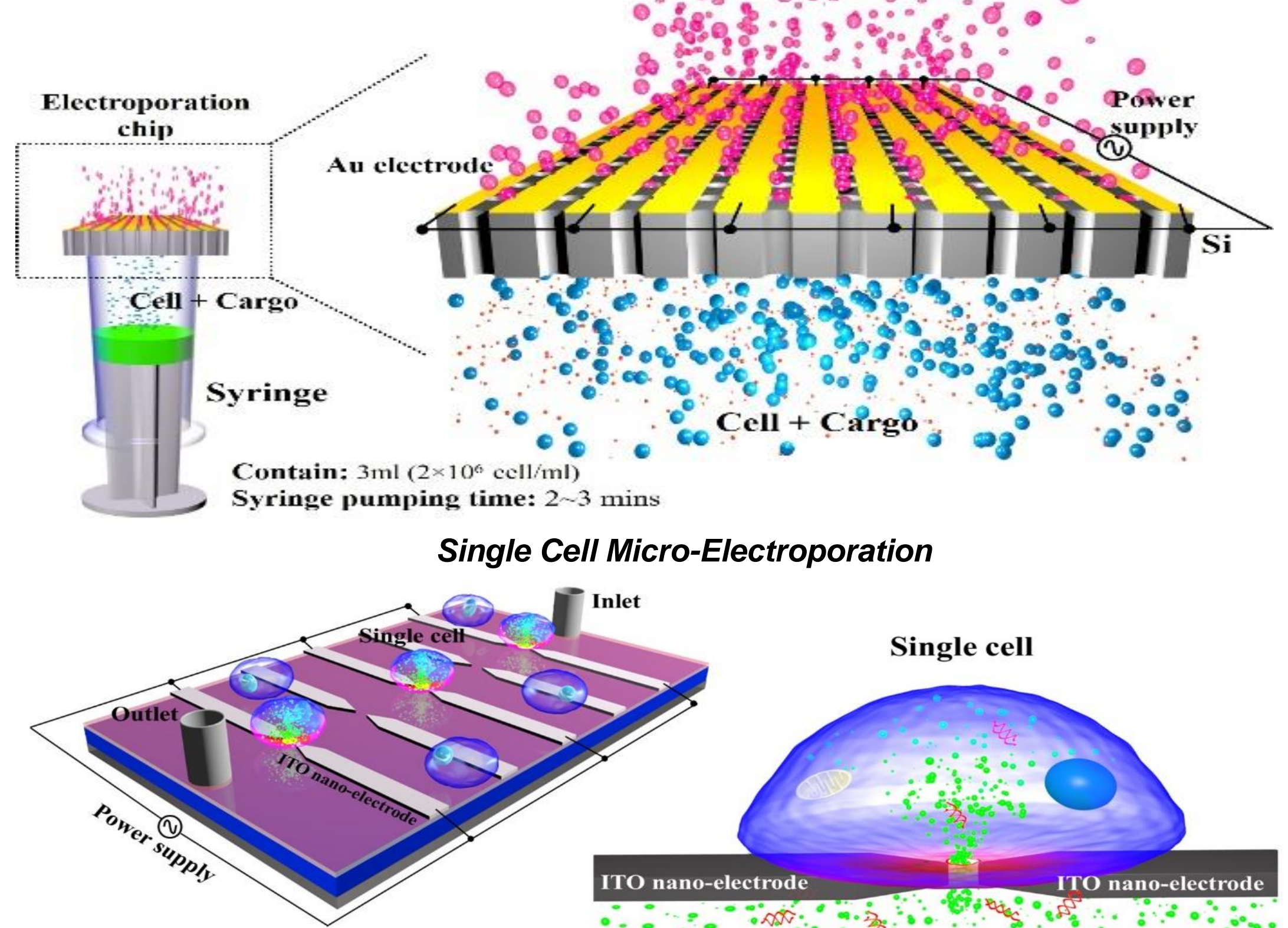


Quantum dots delivery and viability



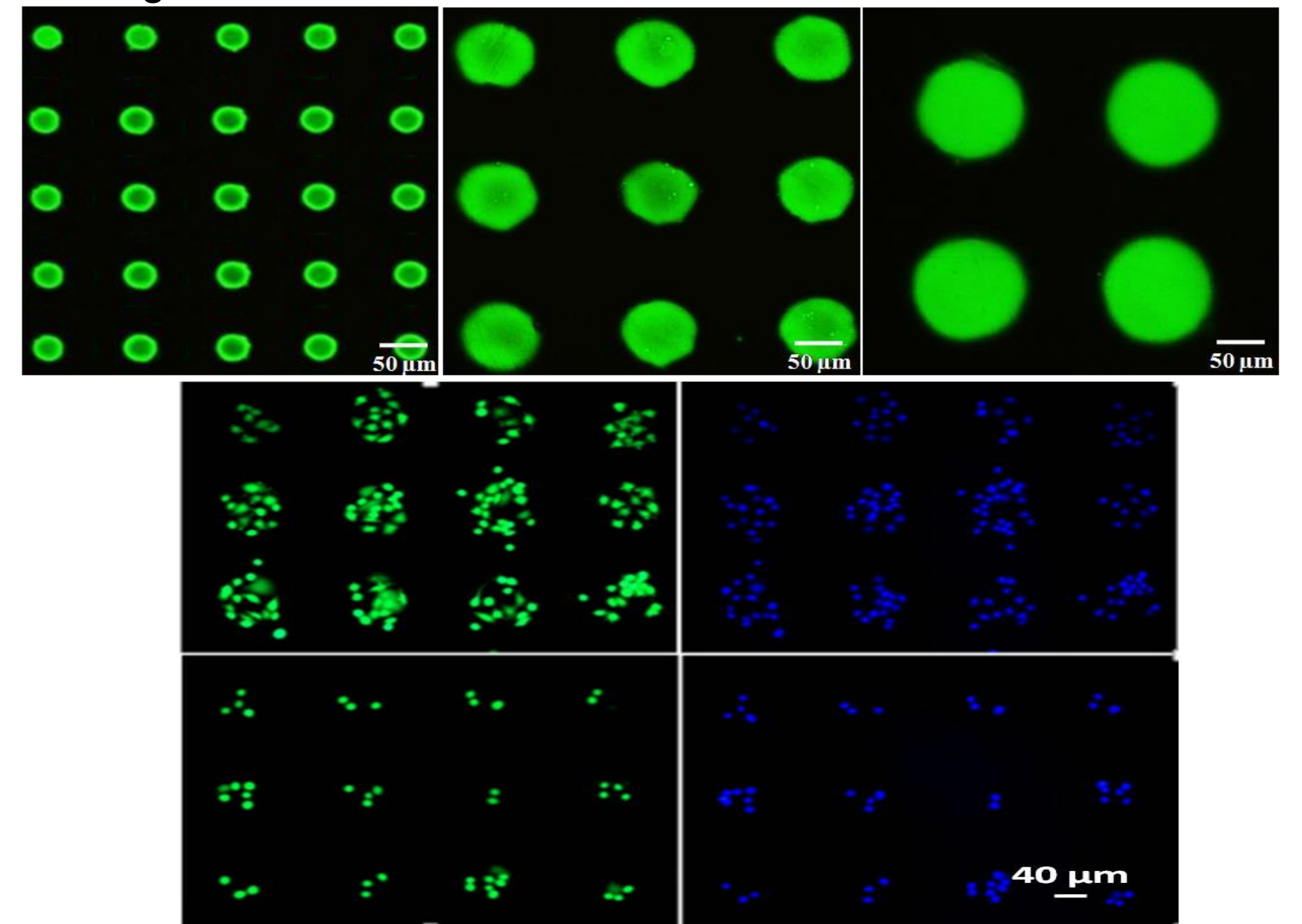
Electroporation

Electroporation refers to the use of electric fields to create reversible or irreversible pores in the cell membrane.



Micro contact printing

The micro contact printing technology is specifically used for 2D alignment of cells on the substrate.



Publications/ Sponsors

- Publications**
- 1) Shinde, P., Mohan, L., Kumar, A., Dey, K., Maddi, A., Patananan, A., Tseng, F.G., Chang, H.Y., Nagai, M. and Santra, T., 2018. Current Trends of Microfluidic Single-Cell Technologies. International journal of molecular sciences, 19(10), p.3143.
 - 2) Kar, Srabani, Mohan Loganathan, Koyel Dey, Pallavi Shinde, Hwan-You Chang, Moeto Nagai, and Tuhi Subhra Santra. "Single-cell electroporation: current trends, applications and future prospects." Journal of Micromechanics and Microengineering 28, no. 12 (2018): 123002.
 - 3) A. Kumar, L. Mohan, P. Shinde, H-Y.Chang, M.Nagai, T.S.Santra "Mechanoporation: Towards Single Cell Approaches" Handbook of Single cell Technologies, Springer. ISBN:978-981-10-8954-1, 2018
 - 4) Pallavi Shinde, Amogh Kumar, Kavitha, Koyel Dey, L. Mohan, Tarun Kumar Barik, Javad Sharifi-Rad, Moeto Nagai, Tuhi Subhra Santra, Physical Approaches for Drug Delivery - An Overview, Elsevier (2019).
- Patents**
- 1) L. Mohan, Srabani Kar, Pallavi Shinde and Tuhi Subhra Santra, Fabrication of Microspikes and Microflowers for Intracellular drug delivery (on submission).
 - 2) Pallavi Shinde, Srabani Kar, Tuhi Subhra Santra, Nanosecond pulsed laser activated massively parallel intracellular drug delivery mediated by titanium micro-dish (on submission).
 - 3) Pallavi Shinde, Tuhi Subhra Santra, 2D substrate protein patterning for cell alignment (on submission).
- Sponsors**
- Department of Science and Technology (DST), Science and Engineering Research Board (SERB) (ECR/2016/001945).
 - Wellcome Trust / DBT India Alliance Fellowship (IA/E/16/1/503062)

Research focus

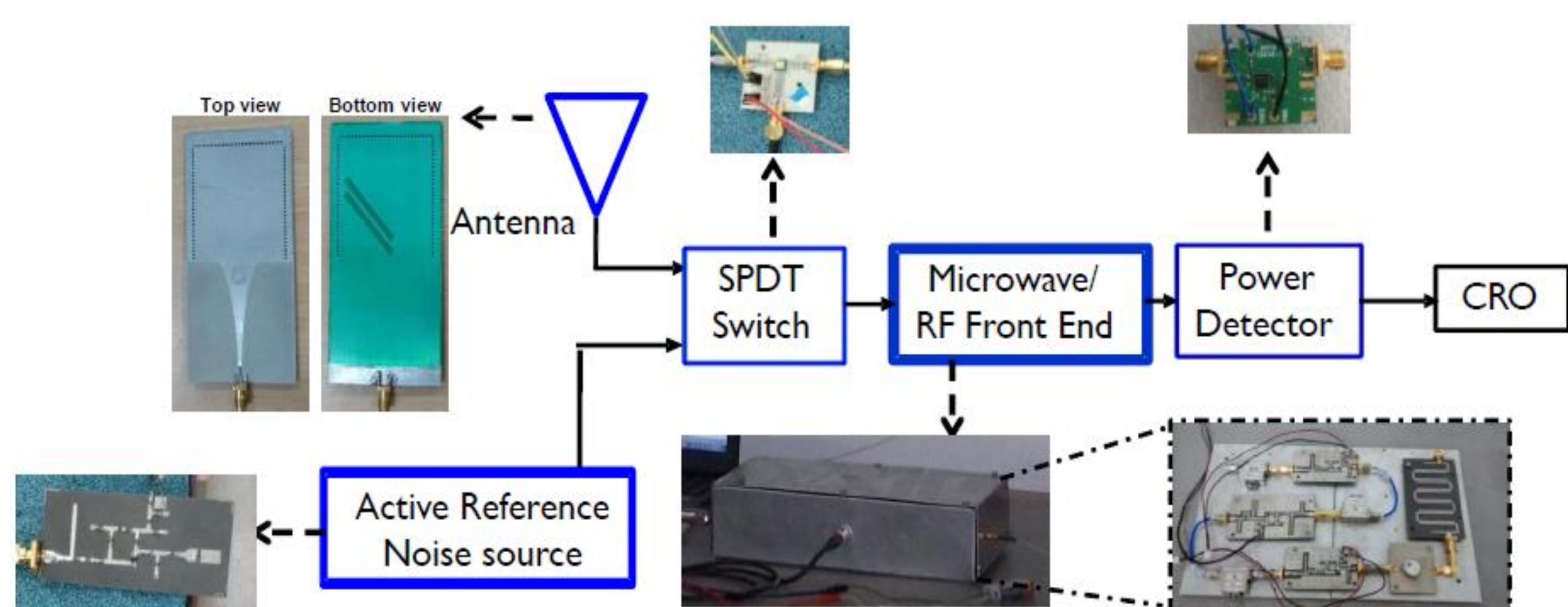
- Microwave techniques for biomedical application
- Design of antennas and RF circuits for diagnostic and therapeutic applications

Research Areas

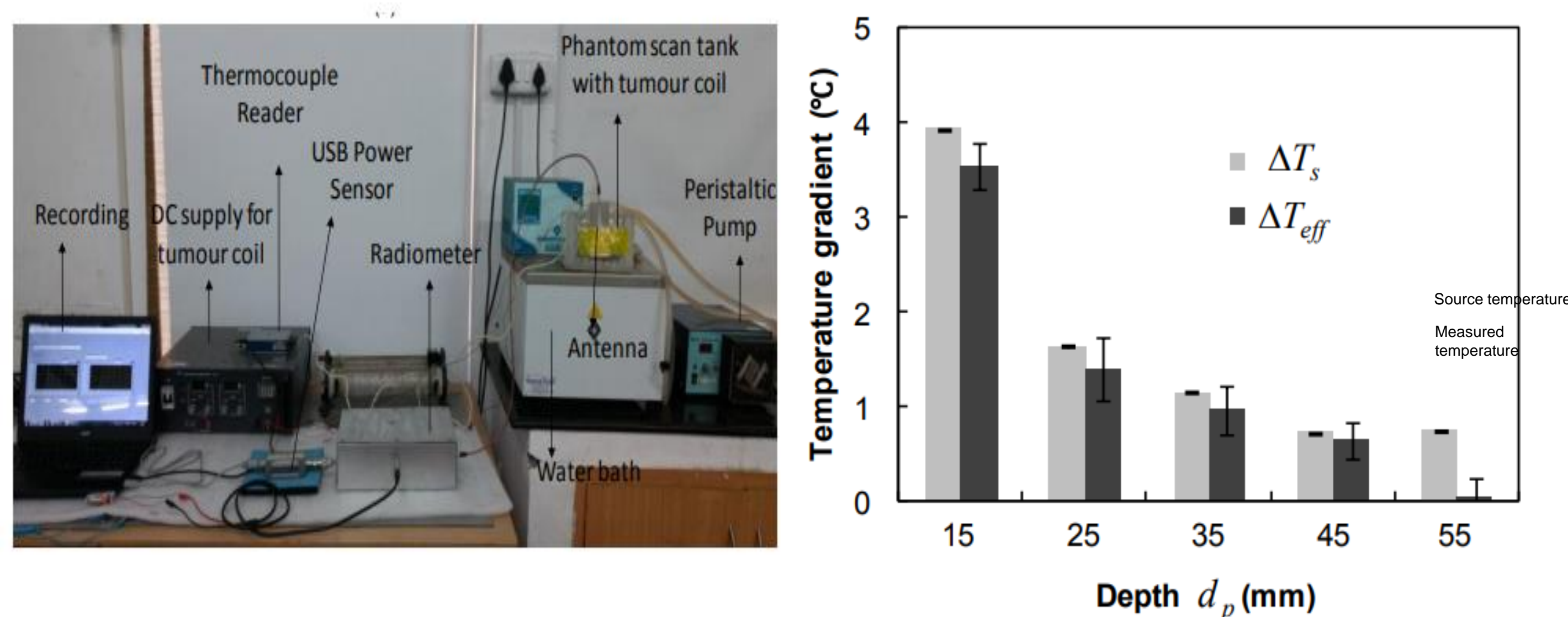
- Non-invasive deep tissue microwave thermometry
- Site-specific phased array for deep tissue hyperthermia treatment
- Intra cavity applicator for hyperthermia treatment of cervical cancer

Microwave Radiometer

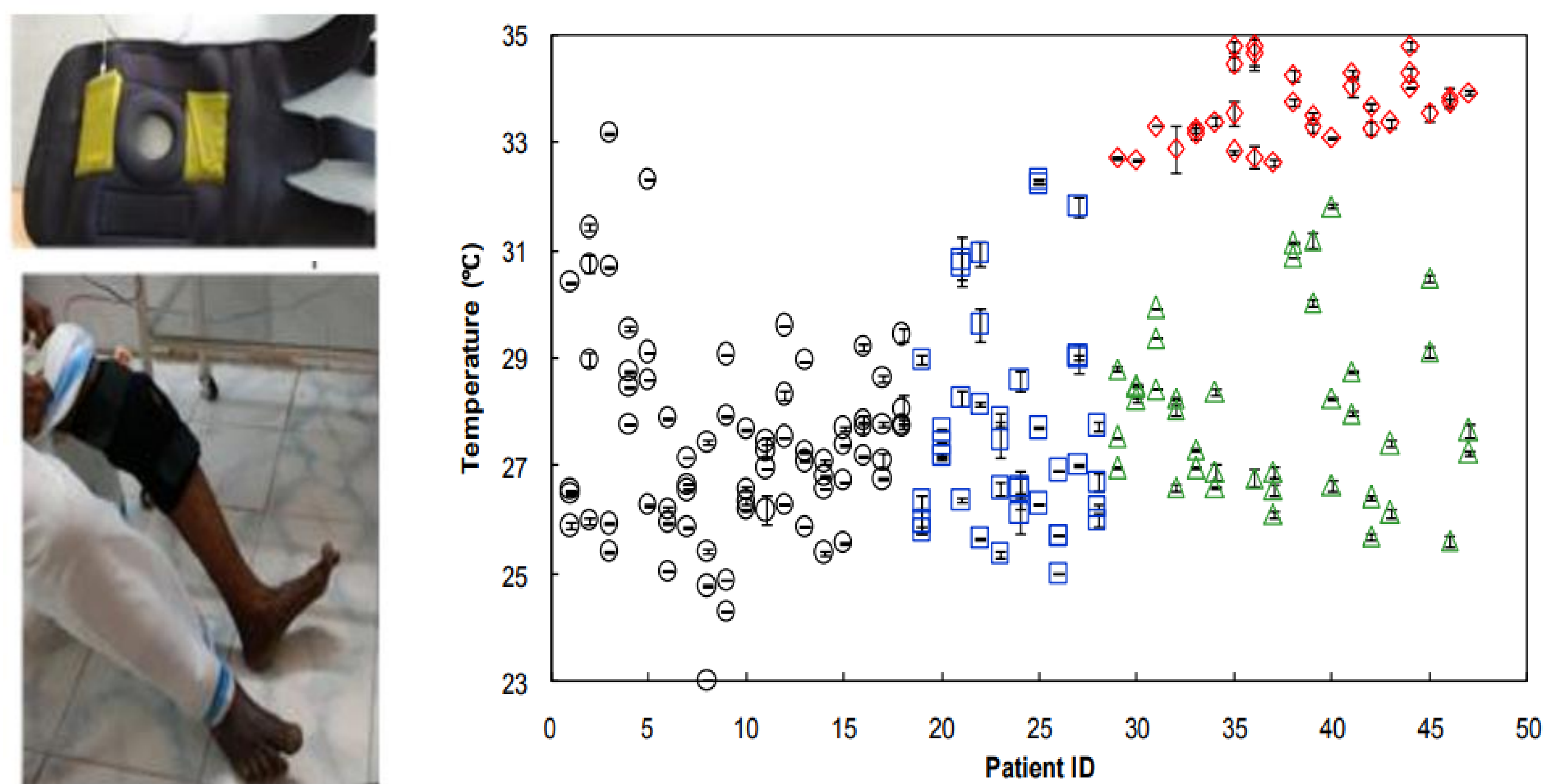
Passive device gathers thermal radiation emitted by body in EM spectrum (1-4 GHz)



Total Power radiometer



Phantom Measurements



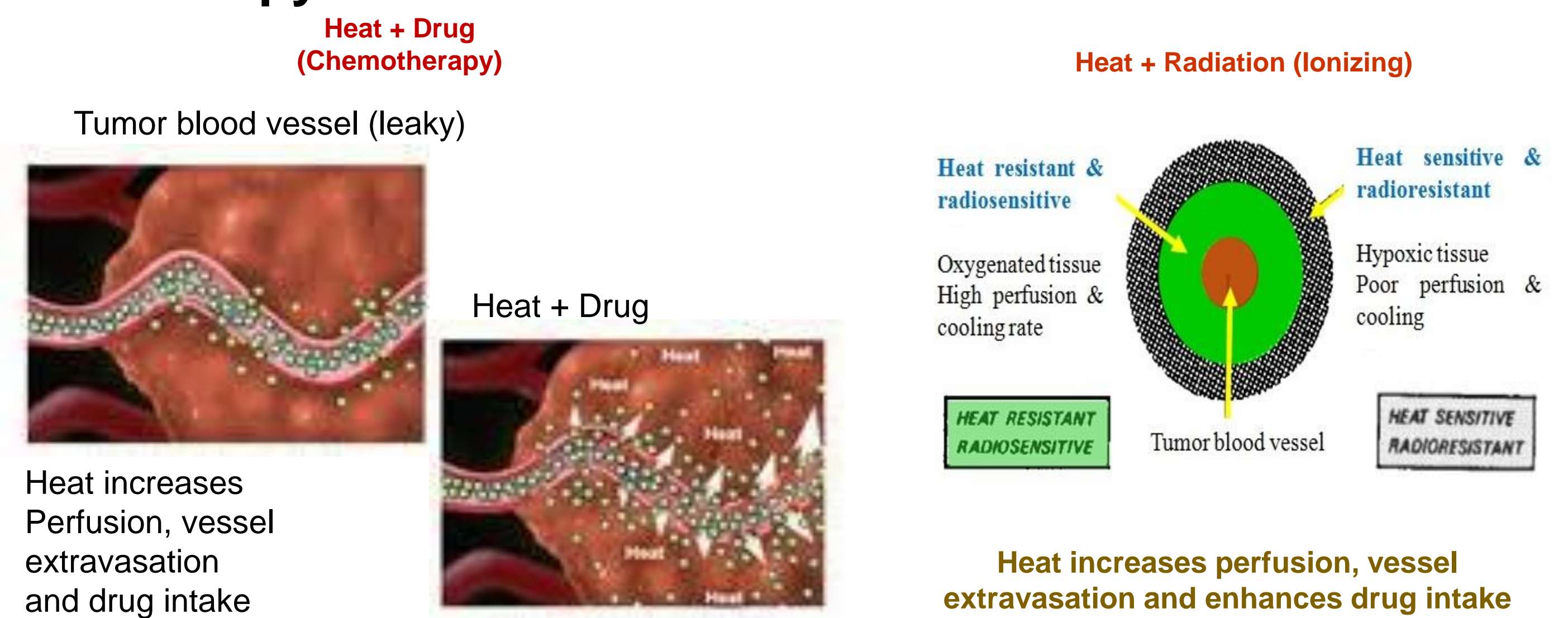
○ Healthy sites of healthy volunteers (age ≤ 35) □ Healthy sites of healthy volunteers (age > 35)
△ Healthy sites of patient volunteers ◇ Unhealthy sites of patient volunteers

Preclinical study

Antenna inside the pouch of orthopedic belt

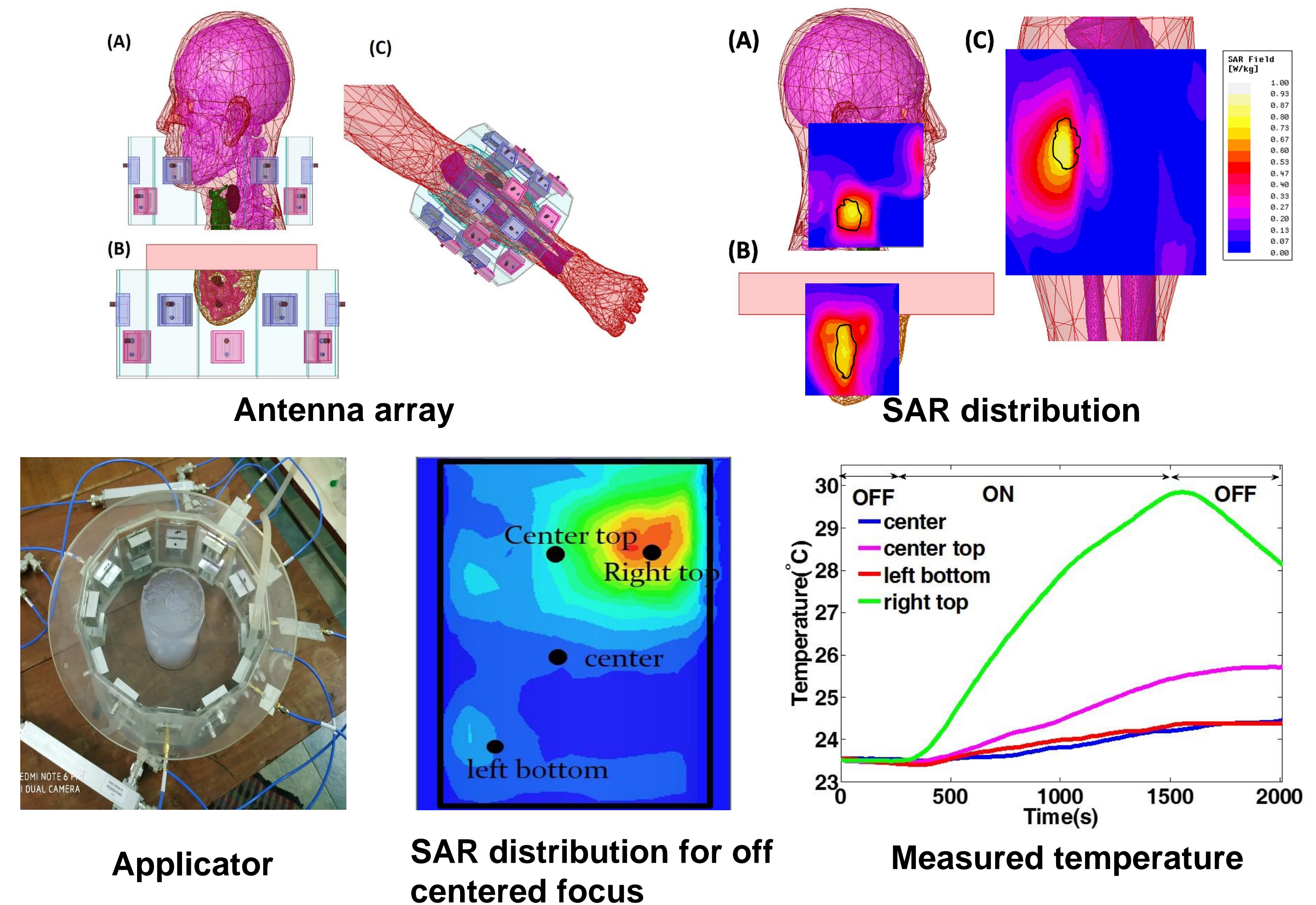
Microwave Hyperthermia

Elevation of tumor temperature (39-45 C) to sensitize for radio / chemo therapy



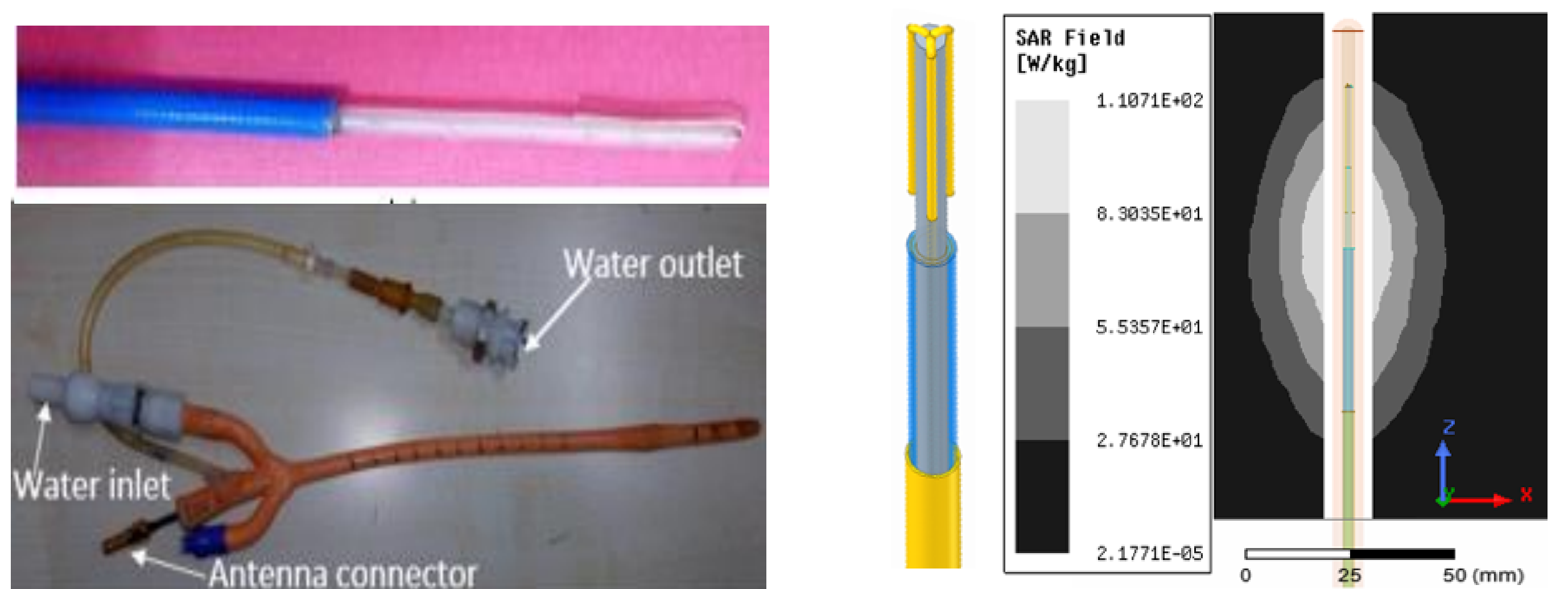
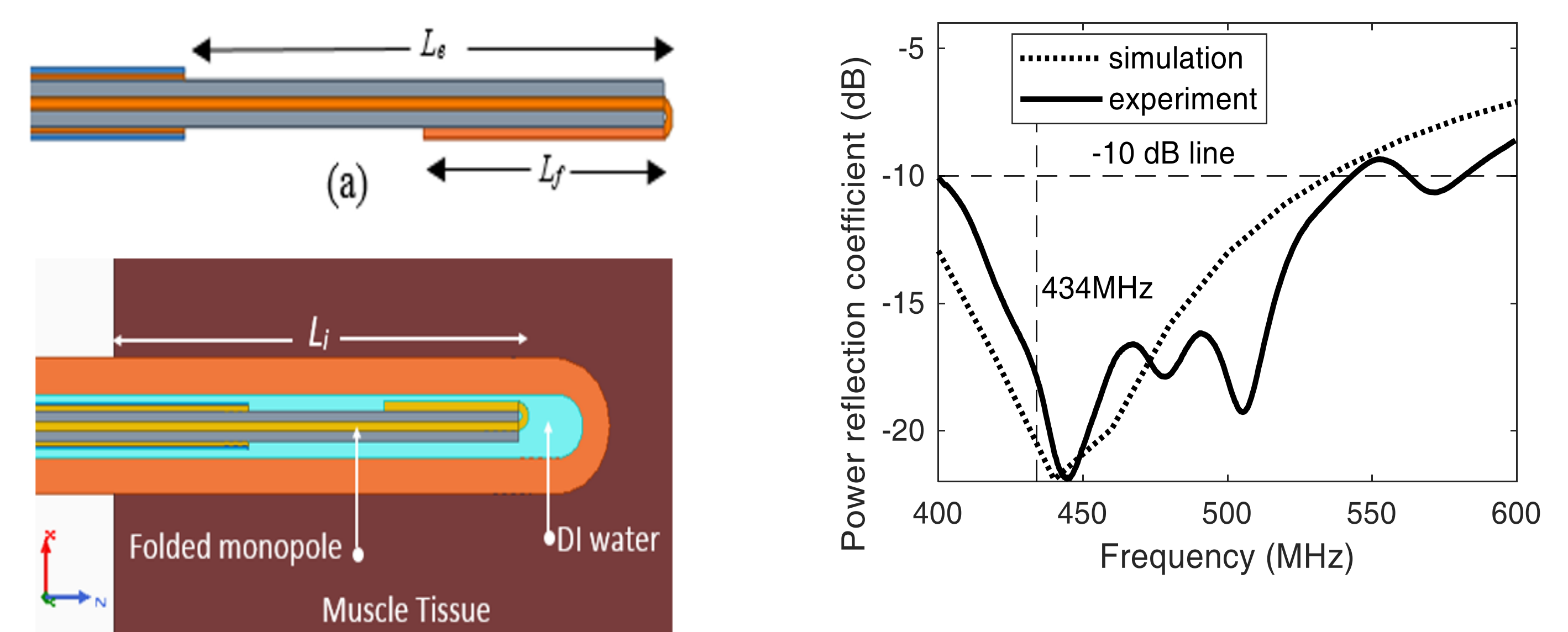
Site specific phased array applicator

Selective heating of cancer while maintaining healthy tissue at normal temperature



Intracavity applicator for cervical cancer

Applicator is placed inside the cavity to deliver heat directly to tumor region



Folded monopole antenna

SAR distribution

Research focus

- Medical Image Analysis and Reconstruction using Deep Learning
- Micro-CT and Optical Imaging System Design & Development
- Deep Learning for Image Registration

Important Outcomes

- Preclinical Imaging System Specifications
 - Energy: 25-50 kV, 0-1mA, Exp.time: 0.19-31s
 - FOV: 30x30 mm (CT), 45x45 mm (Planar Imaging)
 - Detector: 48x48 mm, Voxel size: 25-100µm
 - CNR: 62% (11 lp/mm) and >95% (5 lp/mm)
 - OCX Detector - Optical & XEOL Imaging
- Developed State of the art pipeline for end to end cardiac MR segmentation and disease classification which available as open source.
- Developed pipeline to analyse black box models used for brain tumor segmentation

Design of Preclinical Imaging System

- Pre-clinical molecular imaging - an essential tool for drug discovery, monitoring therapeutic efficacy and disease progression in rodents
- µ-CT system with high frame rate(1-163) detector (small animal coronary angiography)
- Cost-effective ECG monitoring device for rodent

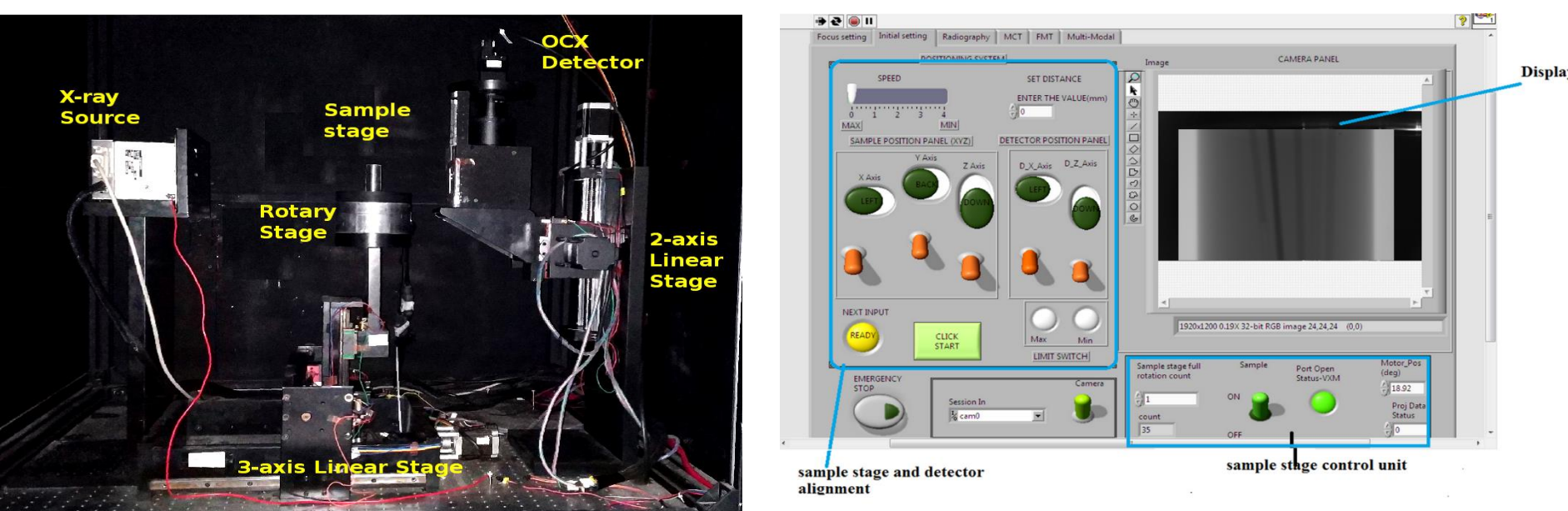


Fig1. In-house Multi Modal Imaging System Fig2. LabVIEW Interface
Applications: Radiography, CT, Fluoroscopy, X-ray Luminescence & Fluorescence imaging

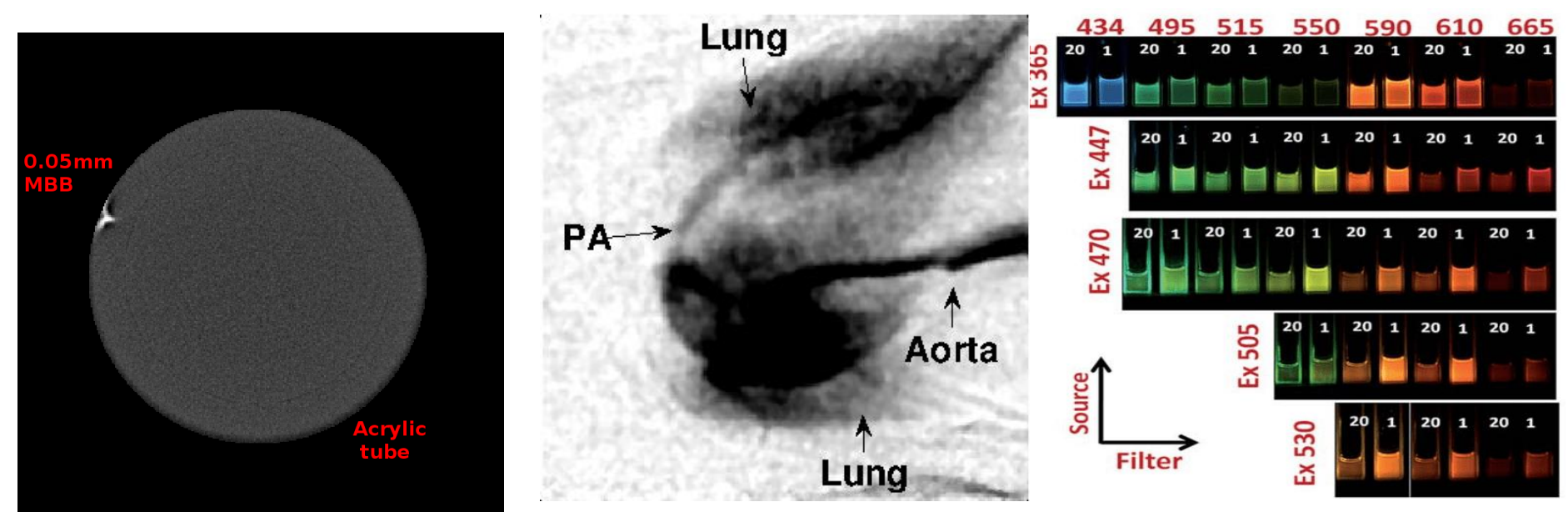
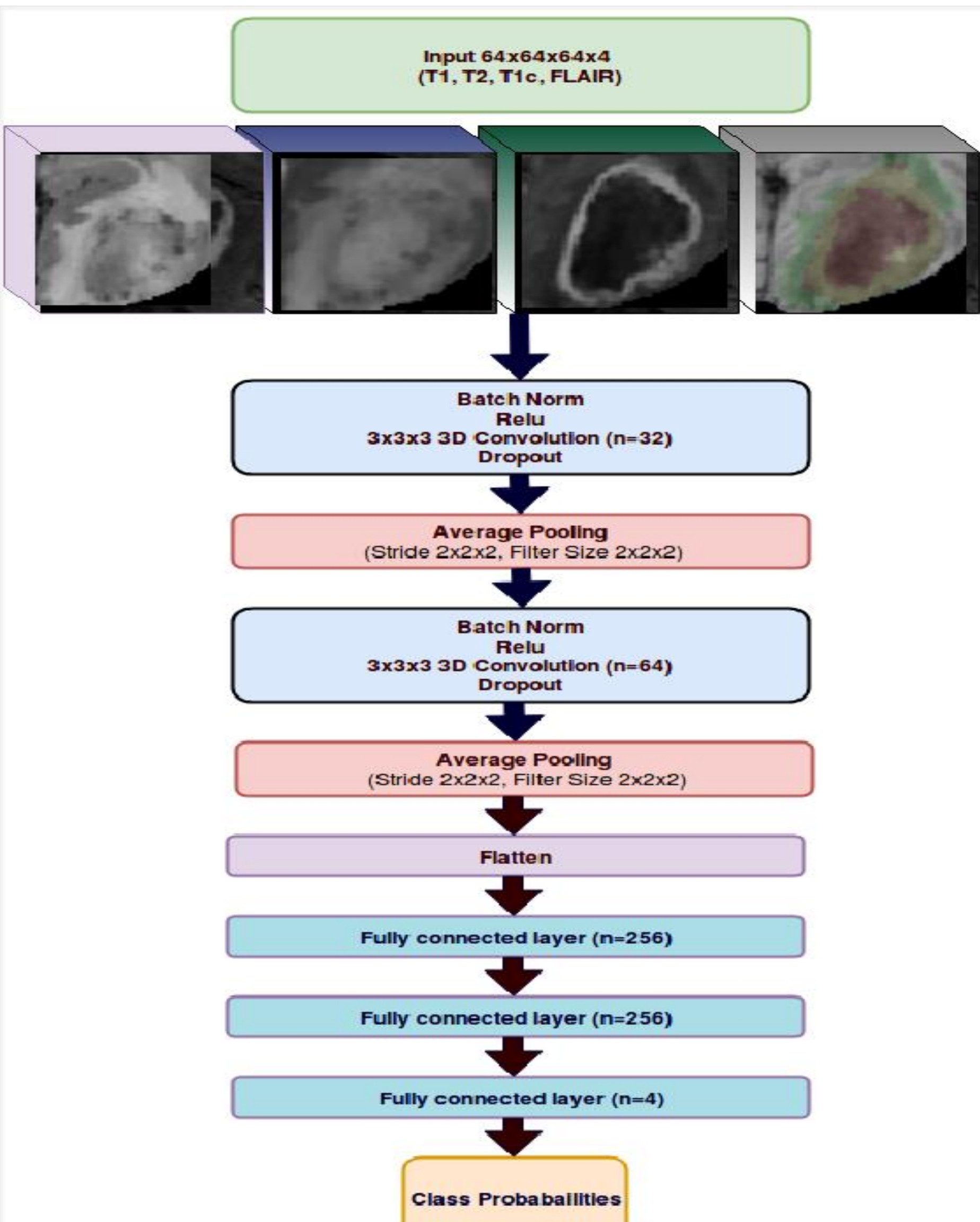
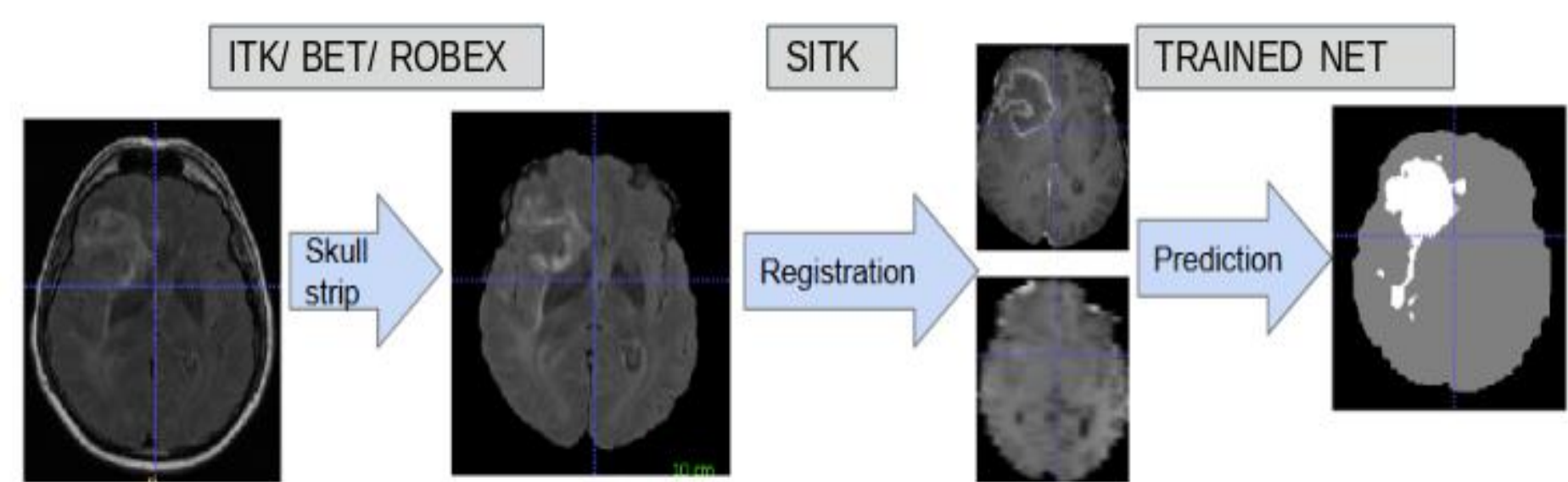


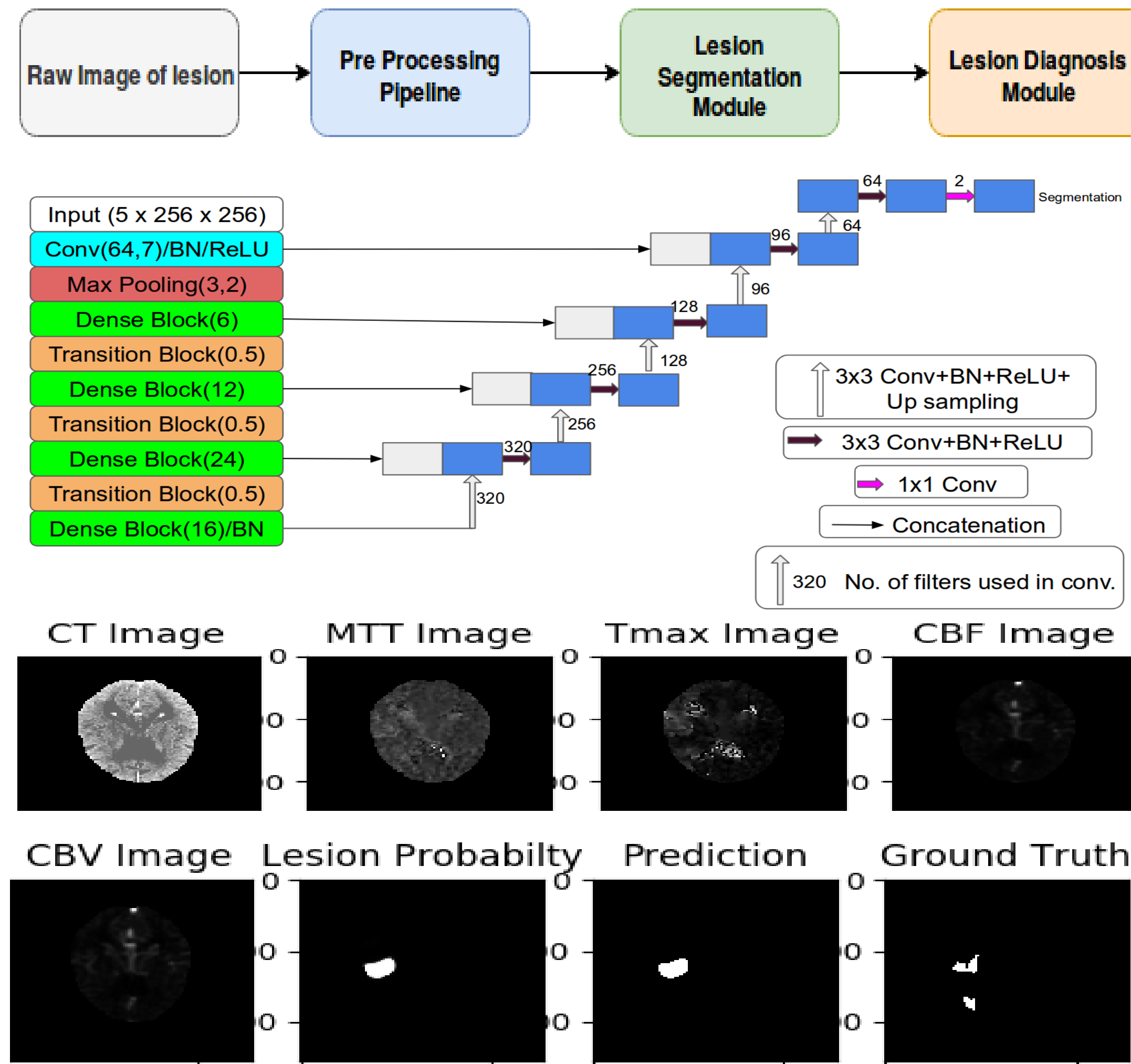
Fig3. Metal Ball Bearing Calibration 35 kV,500mA,2fps
Fig4. Fast frame rate rodent Cardiac Study 50kV,900mA,41fps
Fig5. Color tunable carbon Quantum Dots, prepared at 20 min, 1 hr

Algorithms for Brain Lesion Analysis:

- 3D Convolution Neural Networks for Molecular Subtype Prediction in Glioblastoma Multiforme.

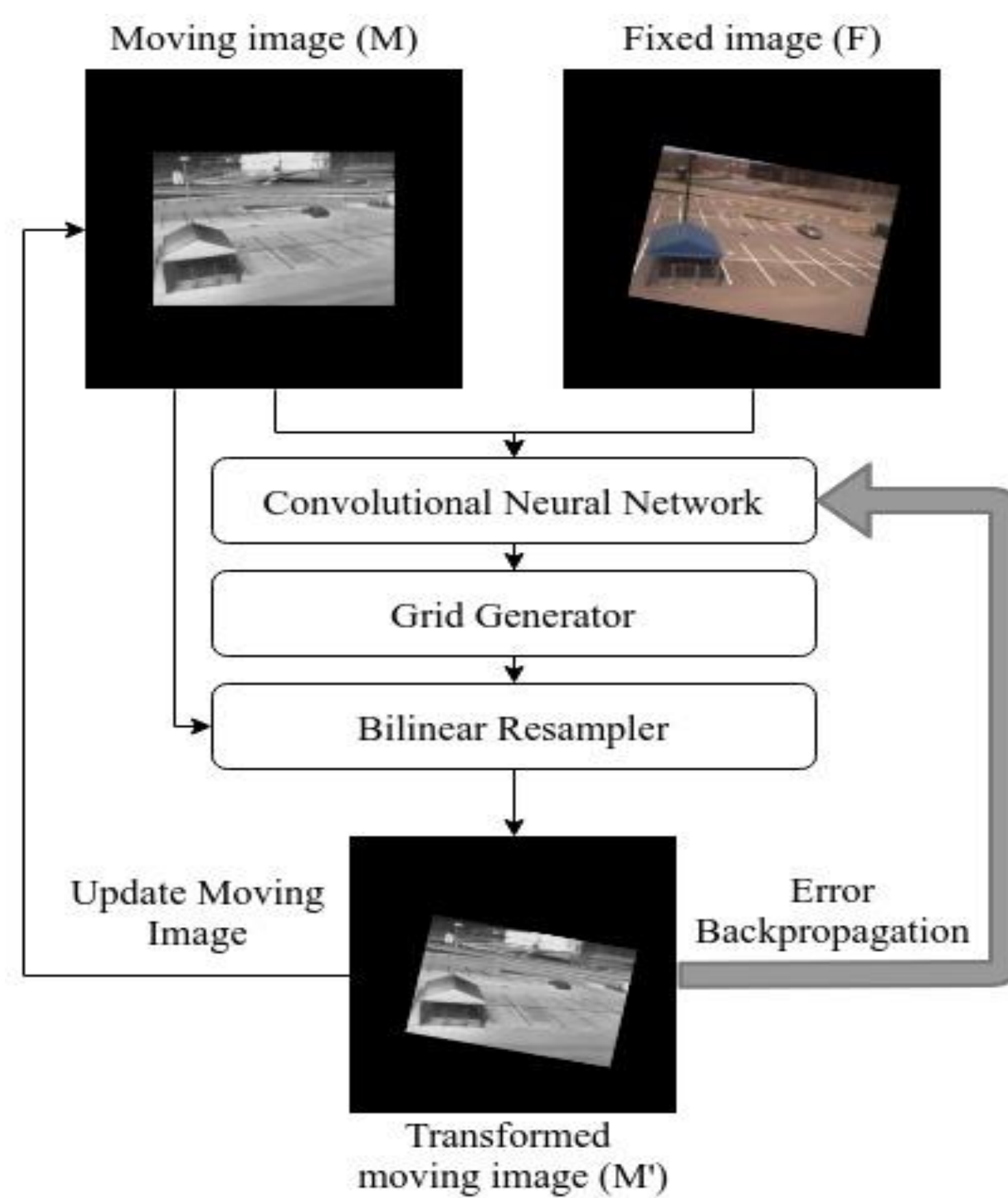


- Fully Automatic Segmentation for Ischemic Stroke Using CT Perfusion Maps



Deep Learning for Multi-Modal Image Registration

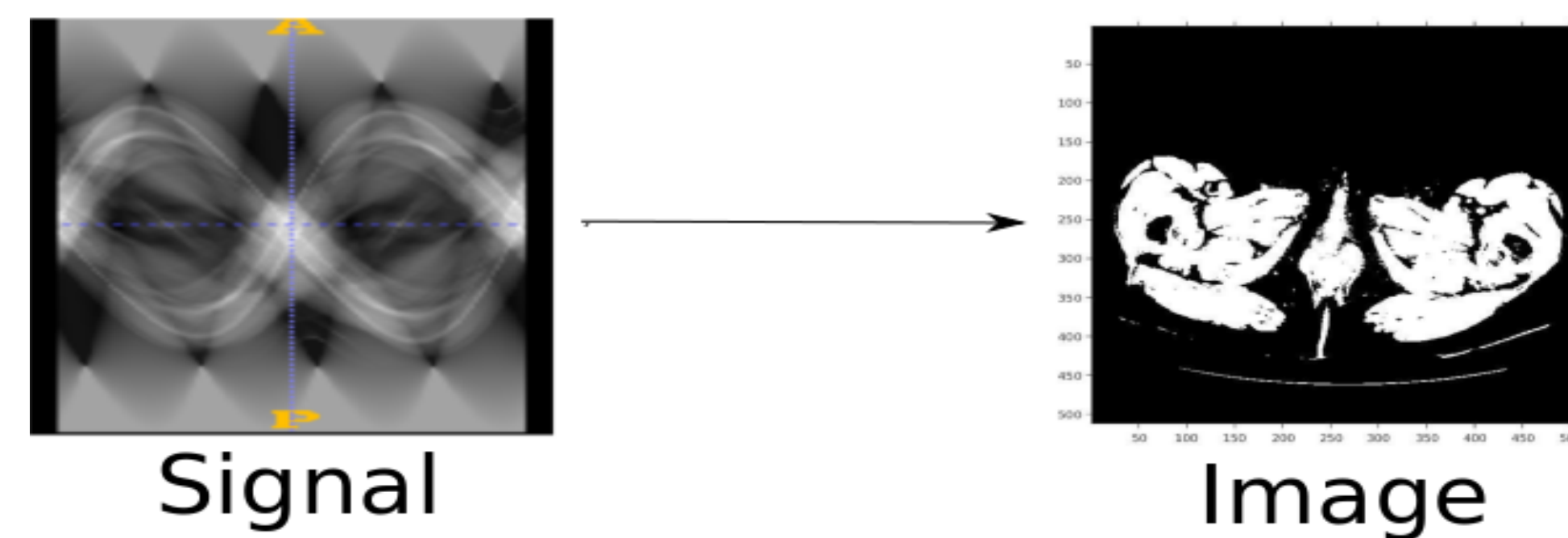
- Spatial Transformer Networks inspired visible-infrared image registration technique.
- Affine transform is initialized as identity transform and gets modified over iterations.



- Learns using a weighted combination of MSE and KL-divergence loss
- Automated registration performed in end-to-end manner
- Returned affine parameters are optimized as well as unbounded
- The registration requires 0.3 seconds for a pair of RGB-IR image

Deep Learning Based Tomographic Image reconstruction

- Deep supervised 2D X-ray CT image reconstruction for fan-beam geometry

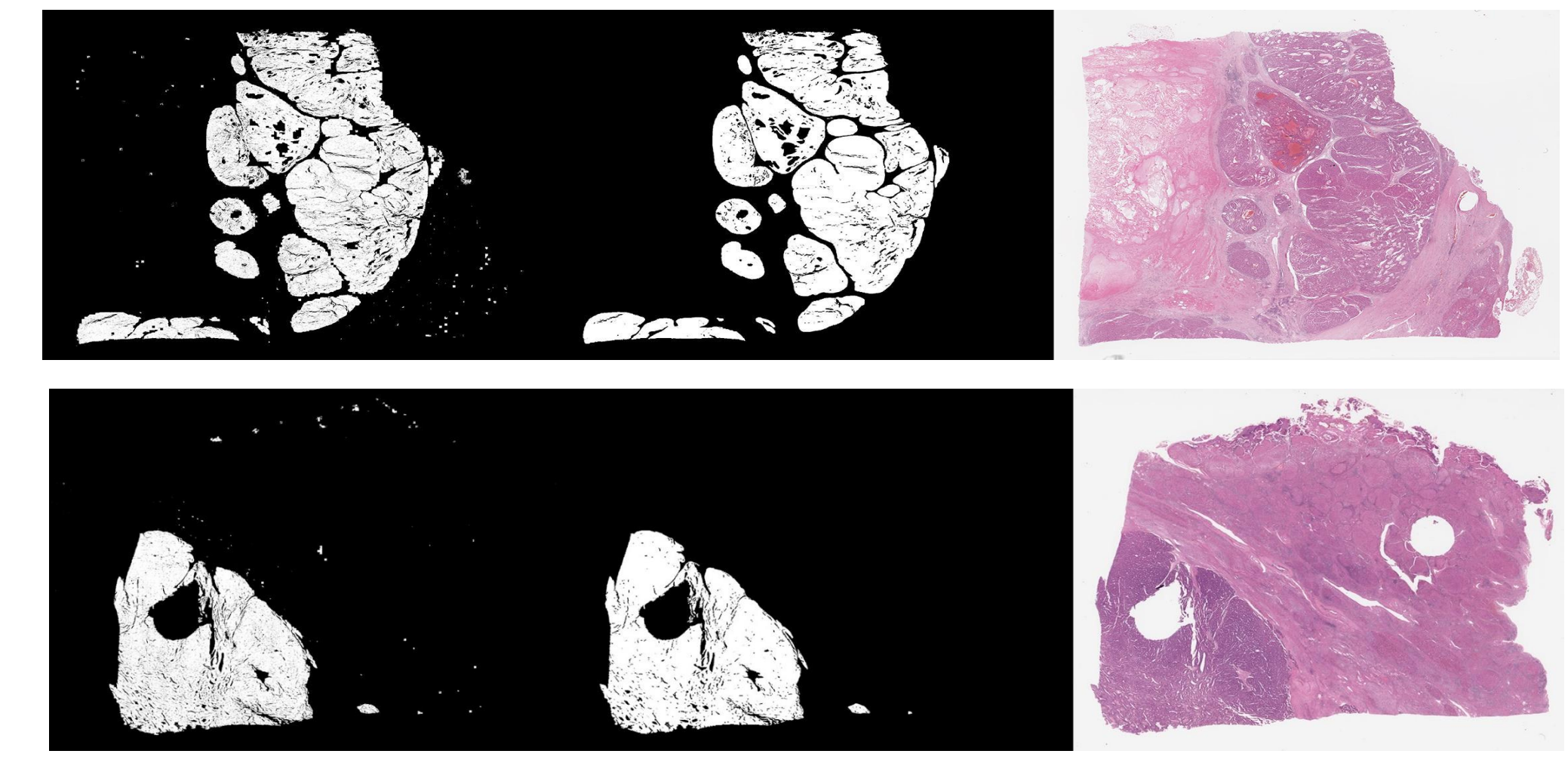


- Develop generative model based X-ray CT image reconstruction techniques
- Develop deep learning models to attenuate image reconstruction artefacts from X-ray CT images

Image reconstruction using architecture proposed by Zhu et. al :-

Fan beam CT reconstruction		MRI image reconstruction	
Original Image	Reconstructed Image	Original image	Reconstructed Image

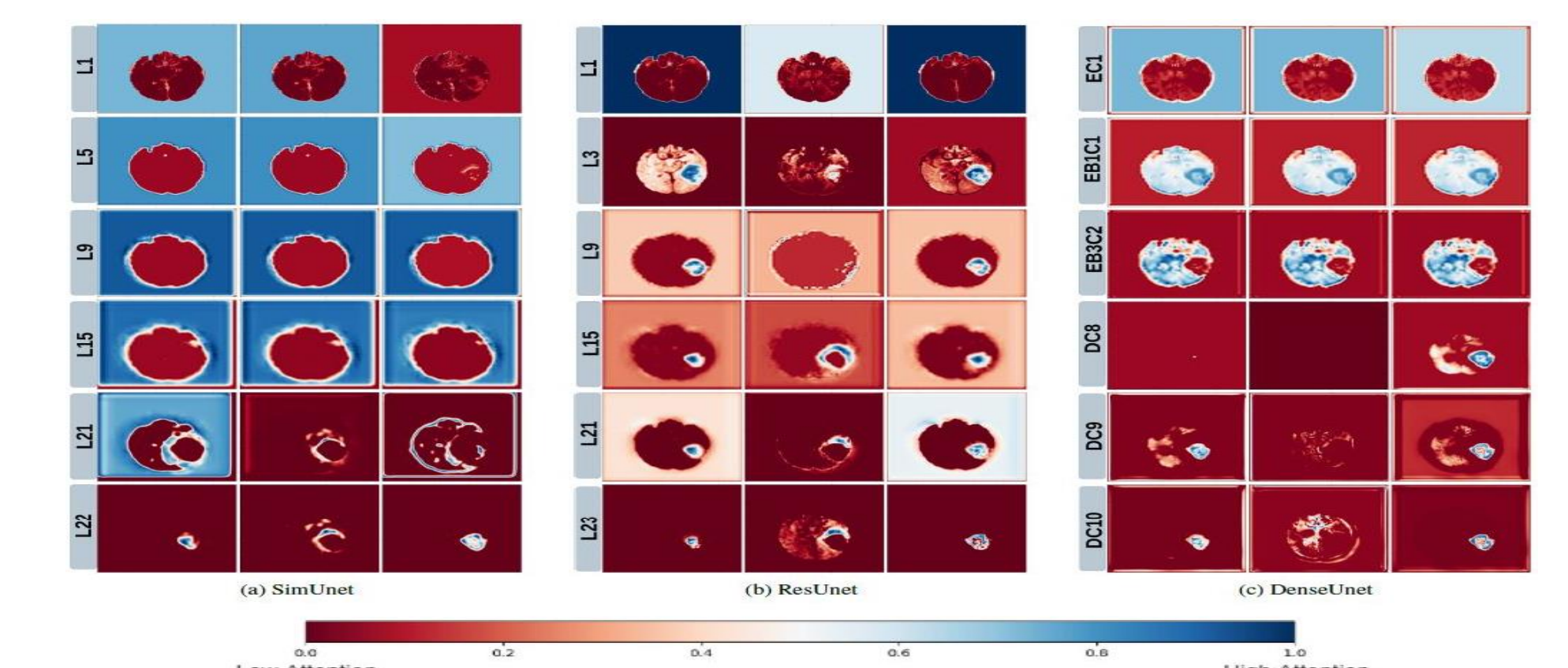
Segmentation of Cancer cells from Histopathology images



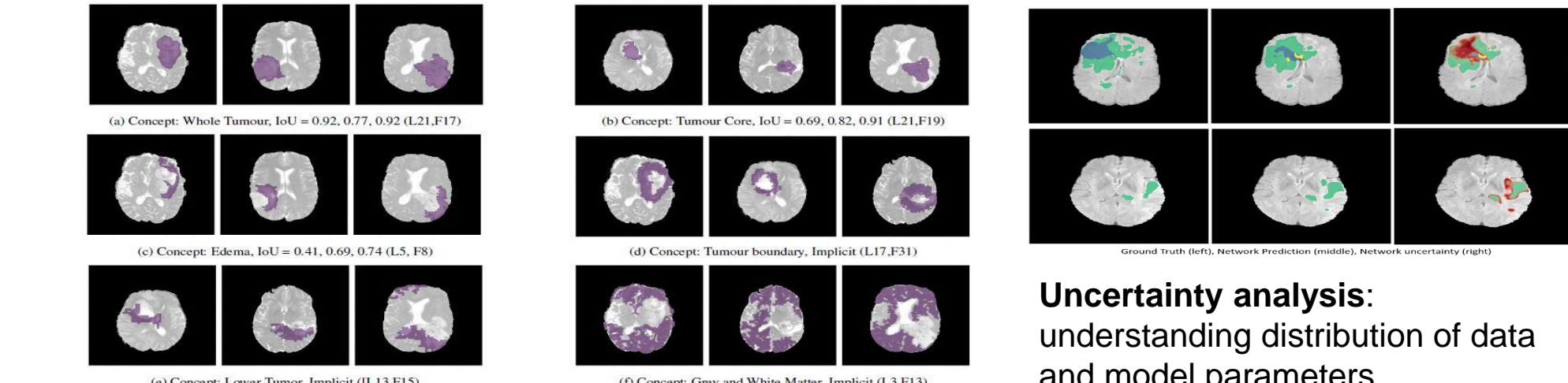
- Segments the tumorous regions from entire histopathology whole slide images
- Uses a 3-model ensemble comprising of diverse architectures to obtain precise segmentation

Interpreting Brain Tumor Segmentation Networks

GradCam analysis: understanding gradient flow information in the network

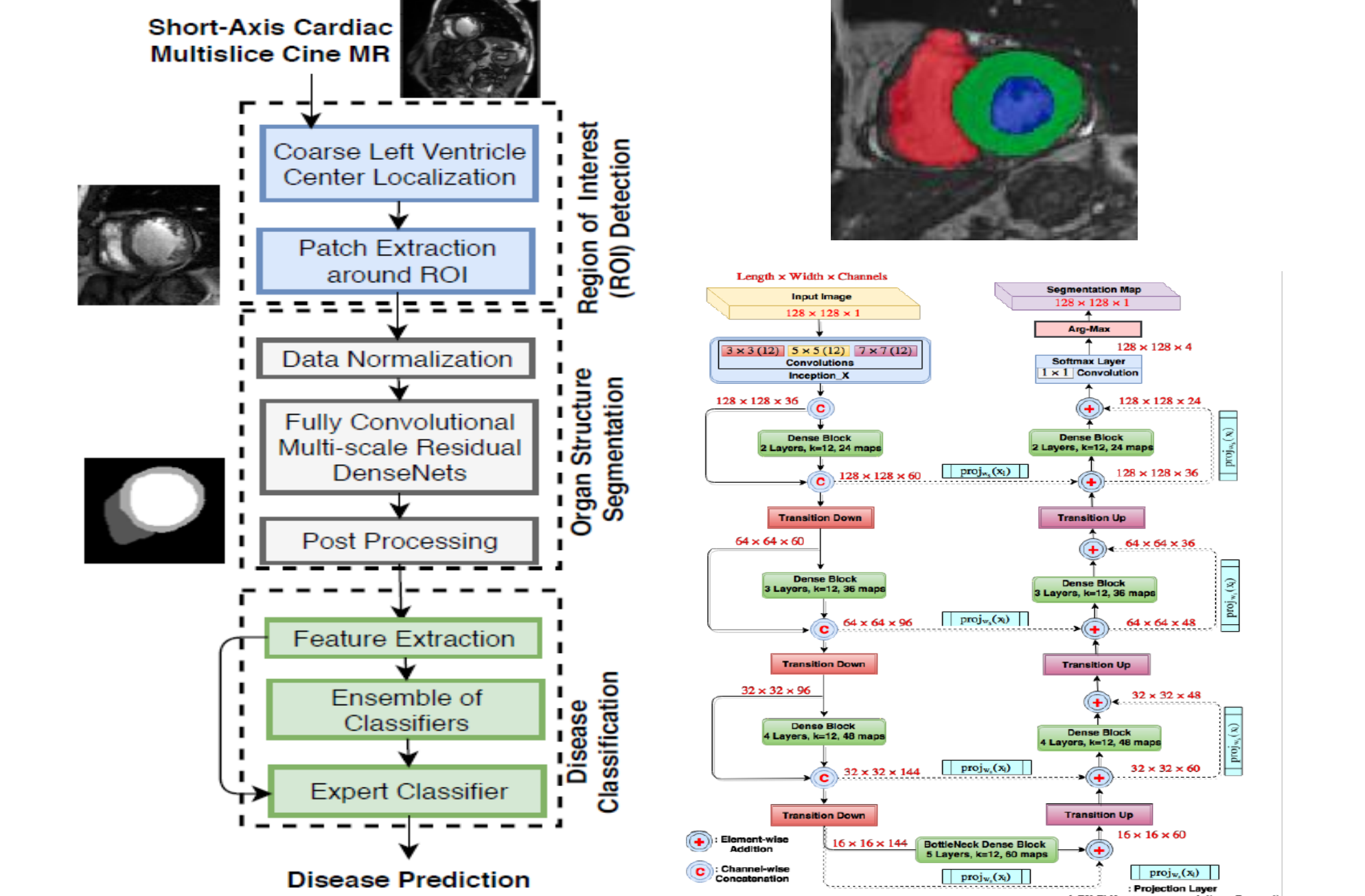


Dissection analysis: understanding functional attributes of each feature map



Uncertainty analysis: understanding distribution of data and model parameters

Automated Cardiac MRI Analysis



- A parameter and memory efficient 2-D multi-scale FCN based on residual DenseNets.
- A novel weighting scheme for combining the benefits of cross-entropy and Dice loss.
- State-of-the-art performance on two challenging cardiac segmentation tasks
- A set of novel hand-crafted features for cardiac disease diagnosis.
- State-of-the-art performance on automated cardiac disease diagnosis.

Publications/ Sponsors

- "Fully convolutional multi-scale residual DenseNets for cardiac segmentation and automated cardiac diagnosis using ensemble of classifiers", M Khened, et al - Medical image analysis, 2019
- "Fully Automatic Segmentation for Ischemic Stroke Using CT Perfusion Maps", Anand et al. *International MICCAI BrainLesion Workshop*. Springer, Cham, 2018.
- Demystifying Brain Tumor Segmentation Networks: Interpretability and Uncertainty Analysis. "arXiv:1909.01498"
- "Fast frame rate rodent cardiac X-ray imaging using scintillator lens coupled to CMOS camera", Swathi Lakshmi B, et al - SPIE Medical Imaging, 2017
- NTIRE 2019 Challenge on Image Enhancement: Methods and Results, The IEEE Conference on Computer Vision and Pattern Recognition (CVPR) Workshops, 2019

Patents

- Multi Modal Imaging System for Pre-clinical Studies (P.No. 201941025672) - Swathi Lakshmi and Dr.GK
- Dual Modality Camera (P.No. 20164103079) - Swathi Lakshmi and Dr.GK

Computational Microfluidic Device Design

Research focus

- Intracellular delivery is a key step in biological research.
- Mechanoporation is intracellular delivery of macromolecules by deforming cells in a microfluidic device.
- Cells are squeezed through a narrow constriction in the channel
- Strain experienced on the cell membrane causes pores
- Diffusion of the target cargo takes place through these pores
- Membrane then recovers from the trauma by resealing of pores
- The research aims to develop a model to study nature of the strain experienced by capsule in microchannel with different geometry

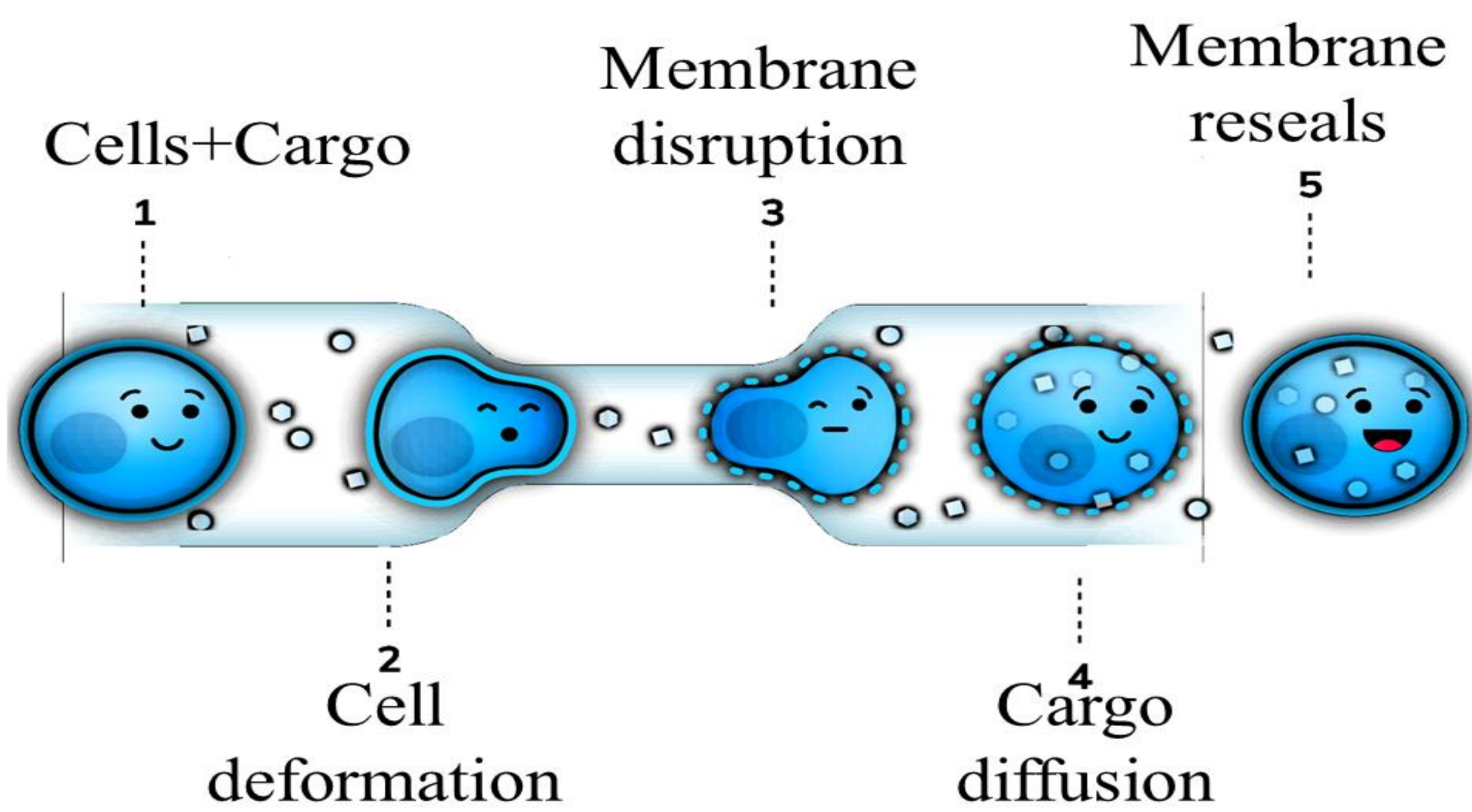


Fig.1 Mechanoporation in a microfluidic device

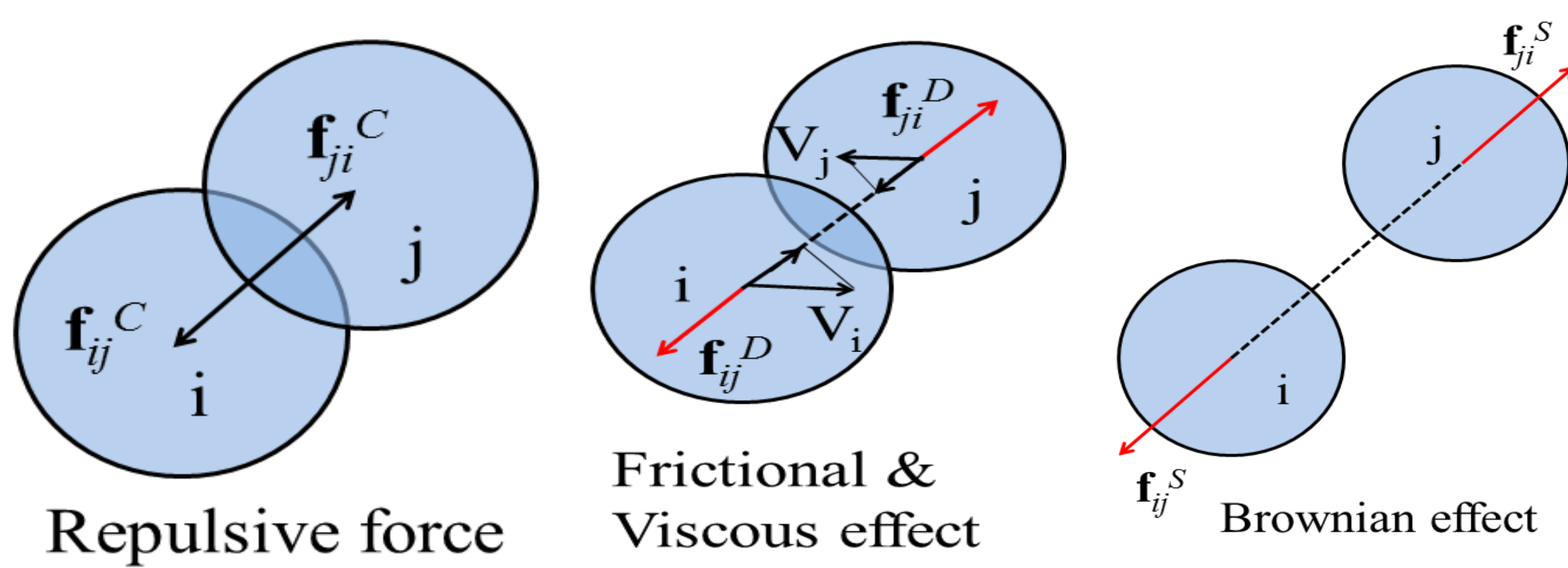


Fig.2 DPD forces acting along the centre of the particles

Computational Methodology

- Dissipative Particle Dynamics (DPD) is a mesoscale model between atomistic scale of molecular dynamics and continuum scale of CFD
- Velocity and position data of DPD particles are determined by Newton's second law of motion

$$m_i \frac{dv_i}{dt} = \mathbf{f}_i^{int} + \mathbf{f}_i^{ext}$$

- DPD forces - Conservative, Dissipative and Stochastic forces
- Capsule is modelled as a chain of particles interacting by linear spring force in the circumference and along radius, and an area constraint
- Instantaneous Wall Boundary (IWB) is used to model no-slip boundary condition at the wall

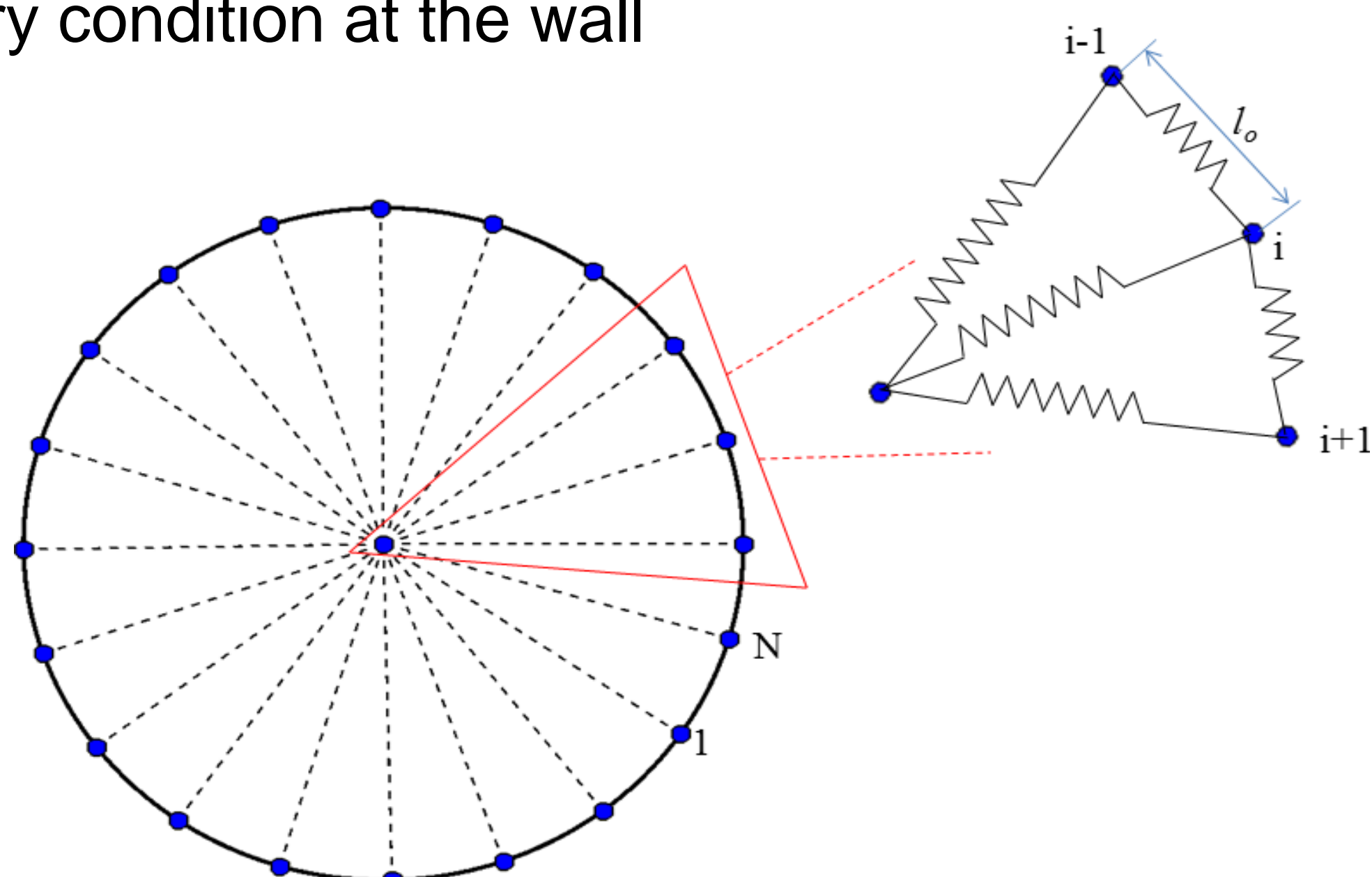


Fig.3 Schematic representation of a capsule model

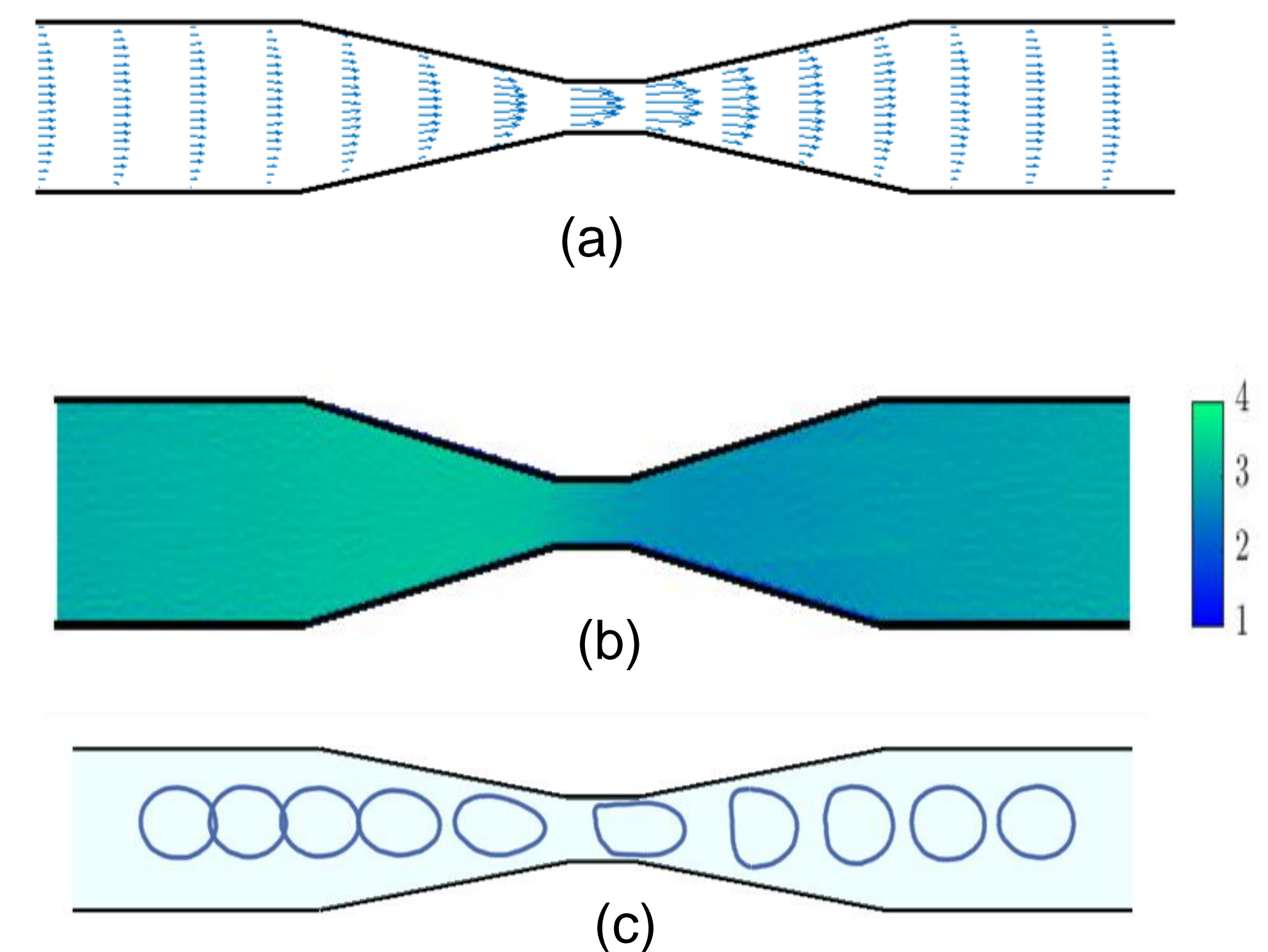


Fig.4 A tapered microfluidic channel showing (a) time-averaged velocity vector plot (b) density contour and (c) snapshot of a travelling capsule

Important Outcomes

- Capsule is deformed by microchannel with constriction width $W = 8r_c, 12r_c$ and $16r_c$
- Strain distribution is uneven throughout the capsule membrane
- Strain on the capsule is influenced by shape of nose cone in deformation and constraint due to the walls

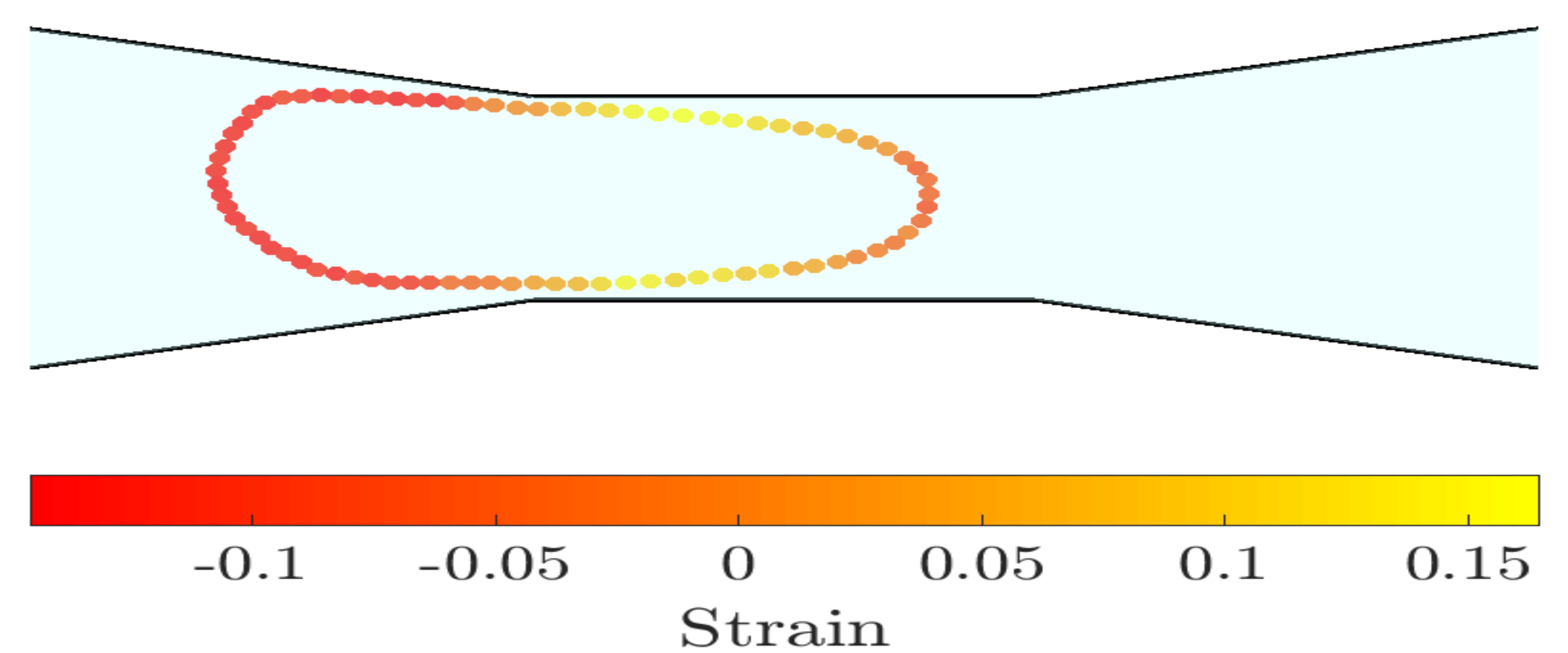


Fig.5 Uneven strain distribution in the capsule membrane

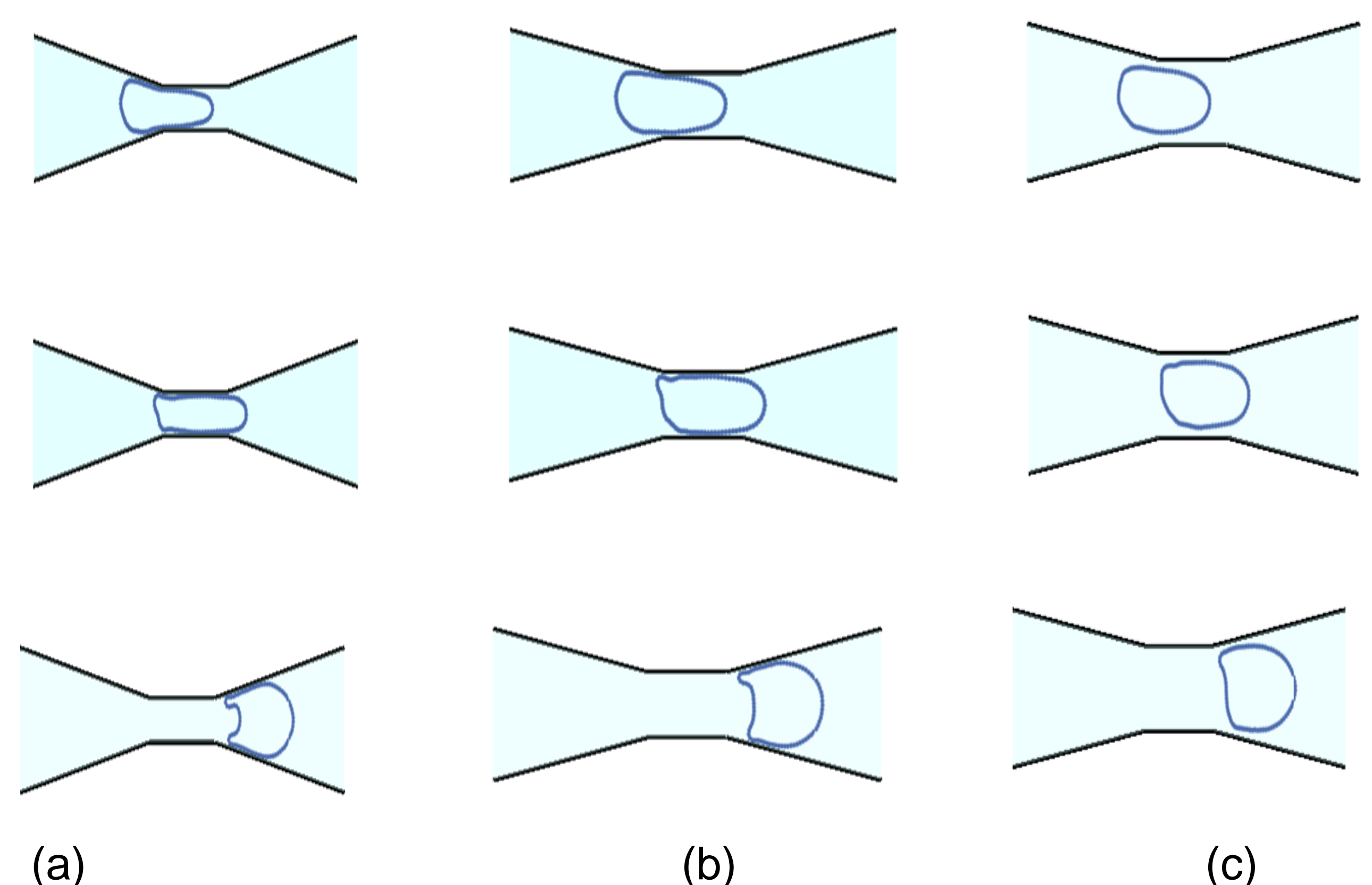


Fig.6 Shape evolution of capsule when deformed by microchannels of varying constriction widths (a) $W = 8r_c$ (b) $12r_c$ and (c) $16r_c$.

Summary

- Higher strain observed in intermediate constriction width
- Pore density can be correlated with the observed strain
- Future work is to investigate strain relaxation after deformation