



*ASME 2010 First Global Congress on
NanoEngineering for Medicine and Biology (NEMB2010)*

Development of Micro-Spectrometer for Neural Probe with Wireless Power Feed

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NASA SAA #15546 Collaboration Activity



Deep Brain Stimulation (DBS) and its Limits

Performance:

Jolt suppression voltage only

- diagnosis and search of anomaly required
- a single function

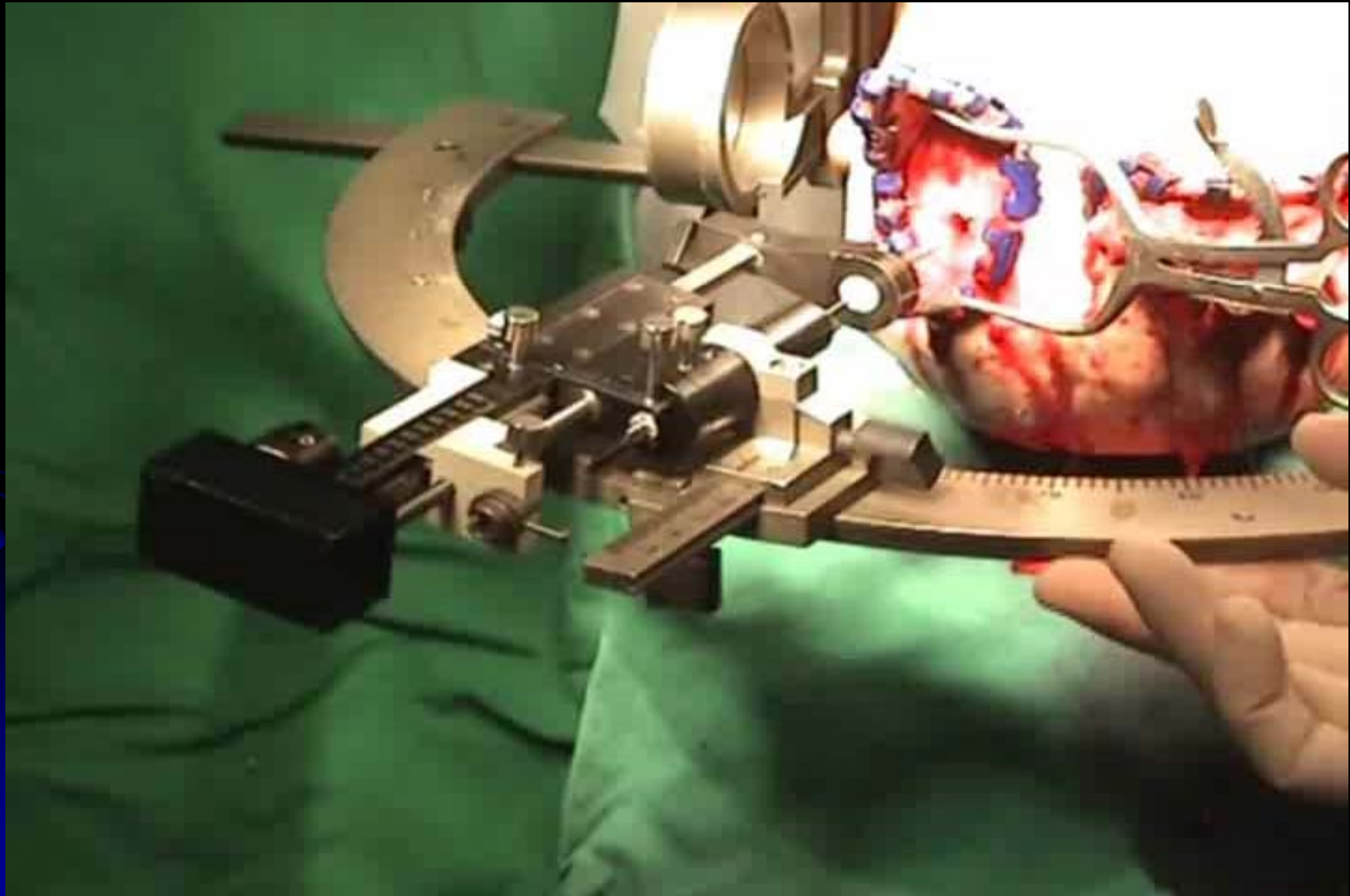
Power Source:

Implanted battery with tether line

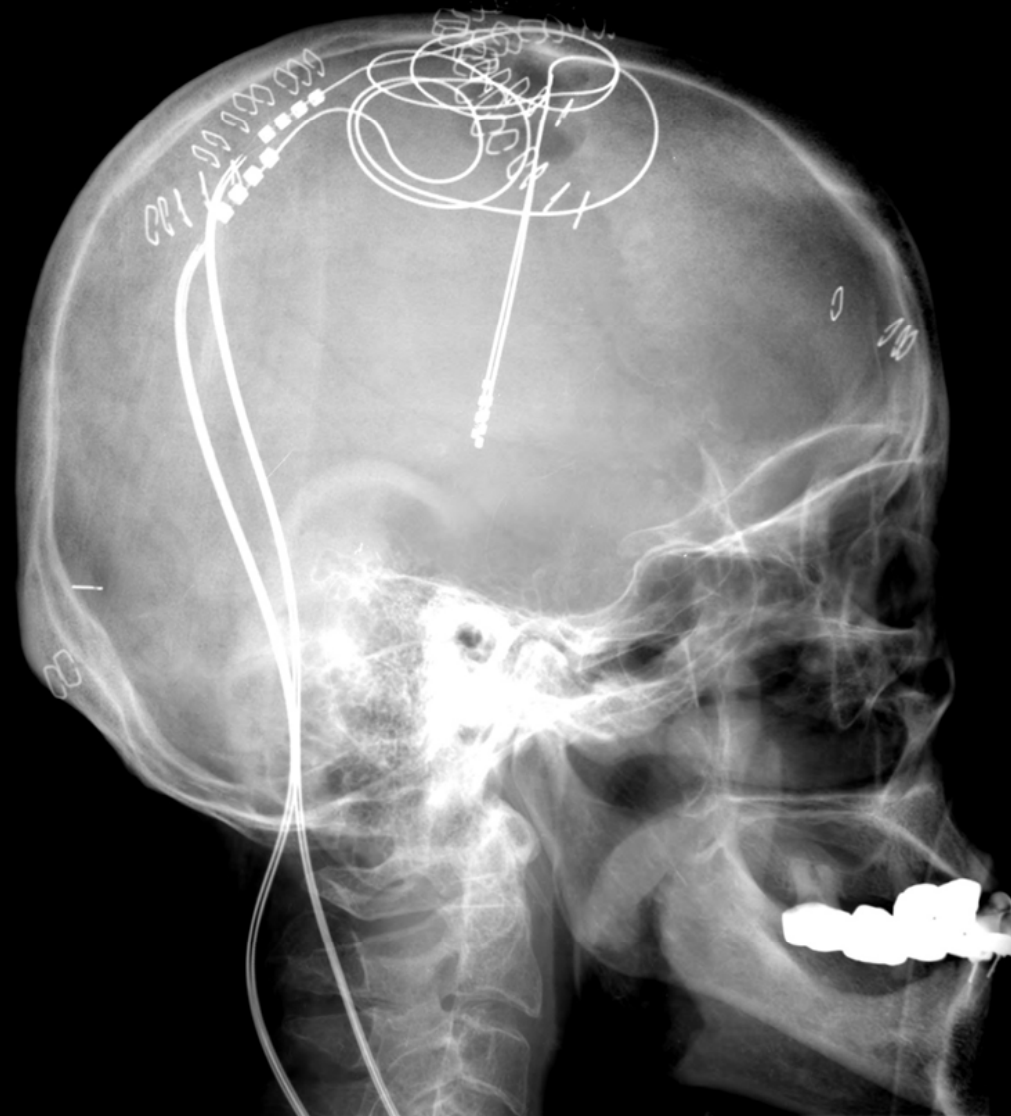
- painful and cumbersome
- battery lasts 3~5 years
- power-line vulnerable to disconnection



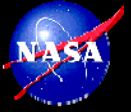
DBS Implantation



Implanted DBS



11 Cm



New Approach: Probe-Pin Device

Performance:

- Diagnosis and search of anomaly required
- Multi-functions integrated
 - Jolt suppression voltage
 - Neuro-chemistry by micro-spectrometer
 - Neuro-electricity
 - Brain temperature
 - Brain pressure

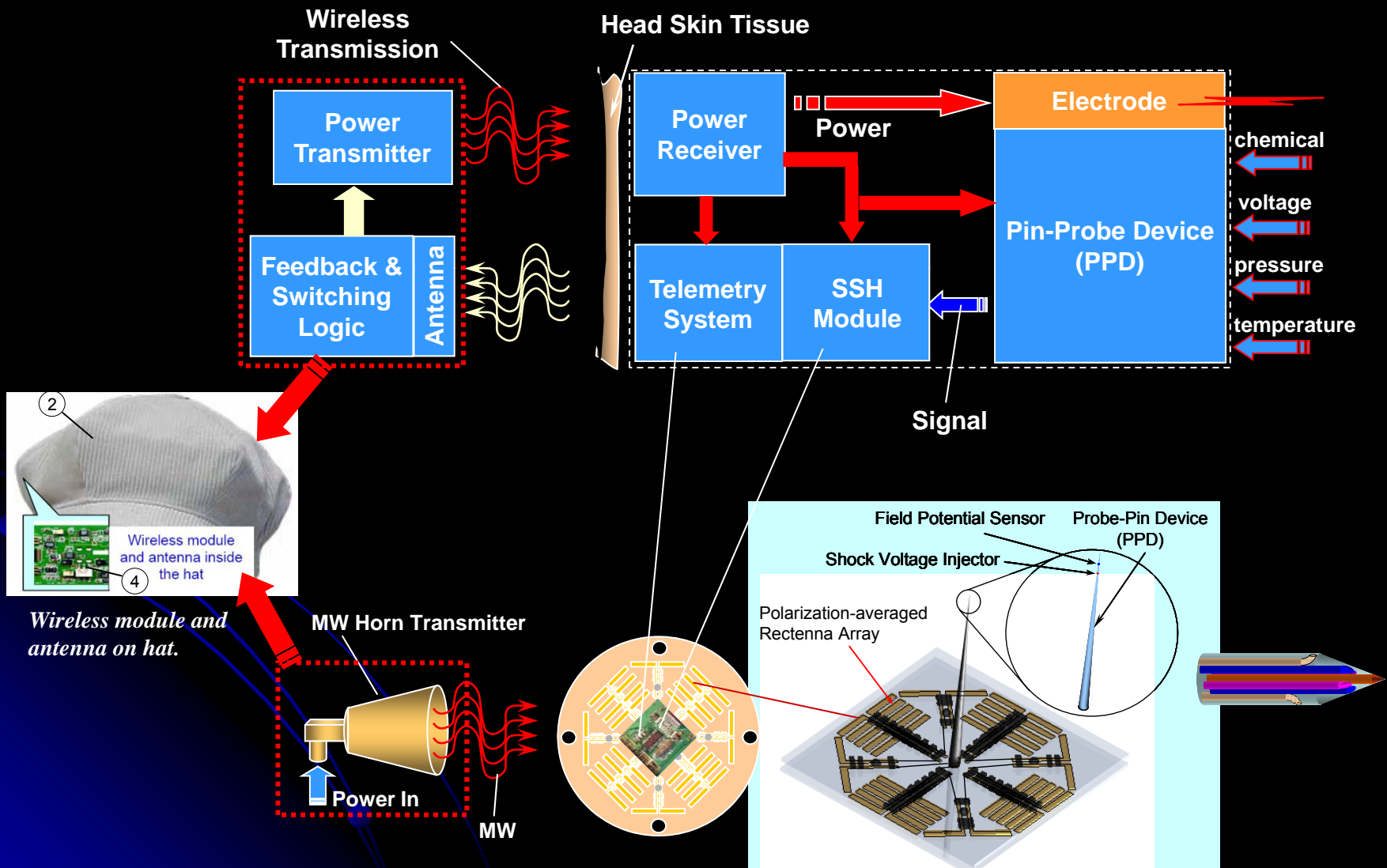
Power Source:

- Wirelessly powered thru human tissue
 - Micro-coil with train of magnetic pulses
 - Rectenna array for microwave coupling

Logic Circuit for Monitoring, Control, and Data Acquisition



Master Logic dependent PPD



Development of Micro-Spectrometer

- Negative Zone Plate (NZP)
- Characterization of NZP
- Breadboard level of Micro-Spectrometer
- Smart Optics Materials for Micro-Spectrometer
- Smart Optics Materials Characterization



9/6/2007
6:46:34 PM

HV
5.00 kV

mag
300 x

WD
5.0 mm

det
ETD

tilt
52 °

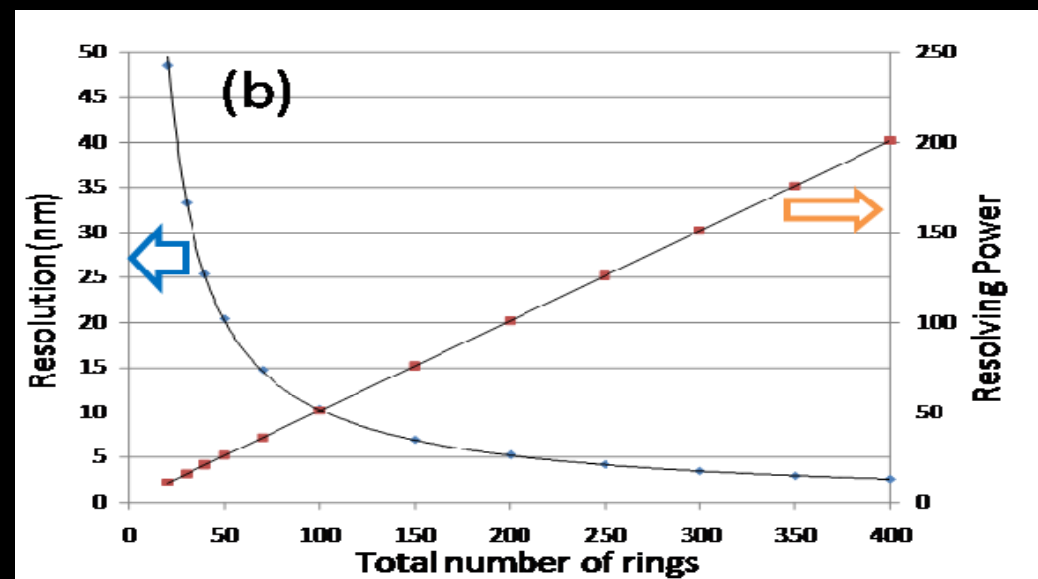
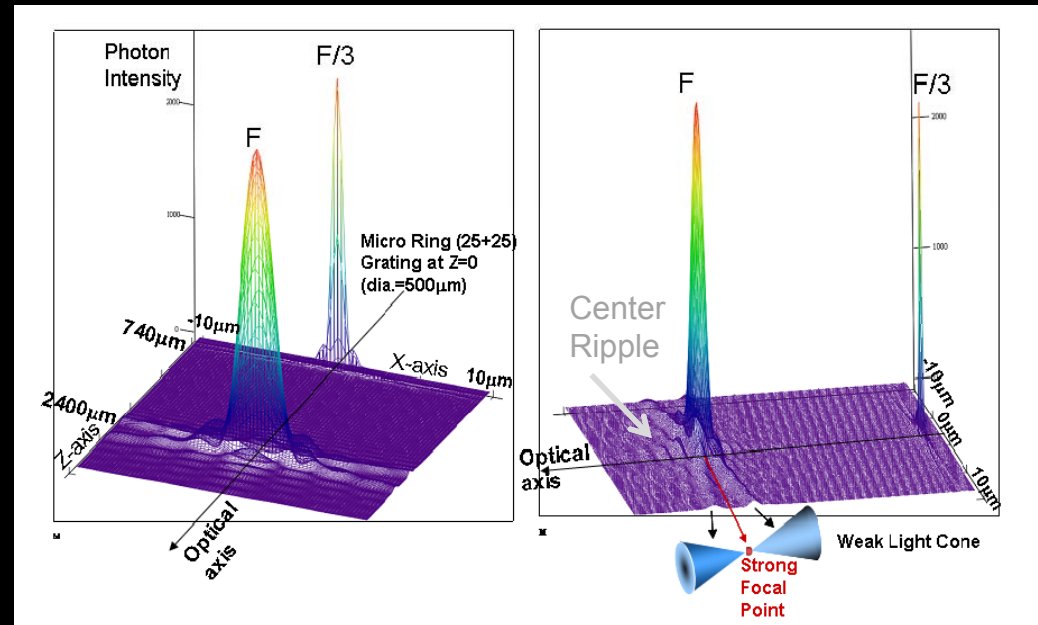
← 300 μm →

KYUNGWON UNIV. RIC

Photon Intensity Simulation for Micro Ring Grating Spectrometer



- ❖ 3-D optical simulation for 500 μm ring grating (25 transparent rings) with Fresnel diffraction.
- ❖ Photon intensity map of optical axis (z-axis) vs. radius direction (x-axis) shows strong focusing effect and spectral separation.
- ❖ Spectral resolution ($\Delta\lambda$) is improved with the increasing number (n) of rings as $1/n$.
 - $\Delta\lambda=20$ nm for 50 rings
 - $\Delta\lambda=10$ nm for 100 rings
- ❖ Each wavelength has a strong focal point which is surrounded by two weak light cones.
- ❖ Circular aperture slit of 1% of the ring grating diameter will pass the photons of a selected wavelength.

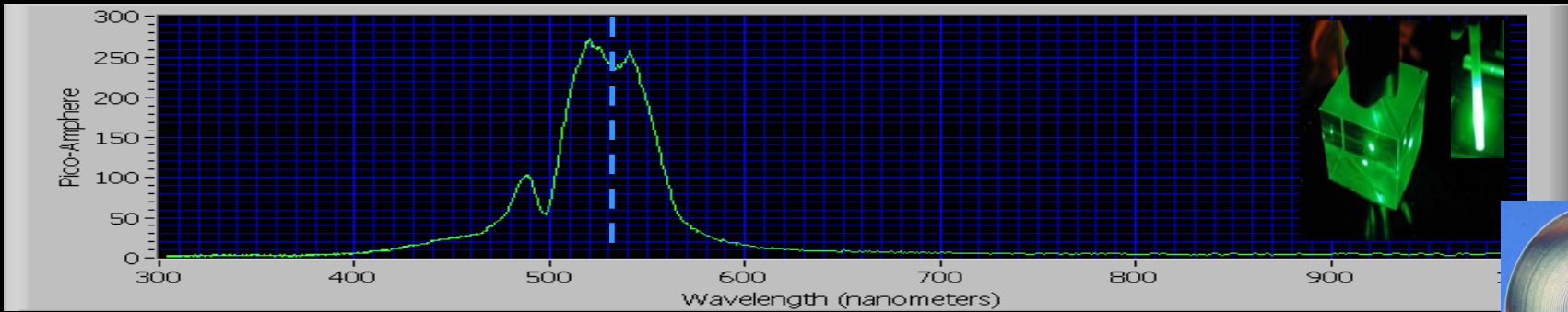




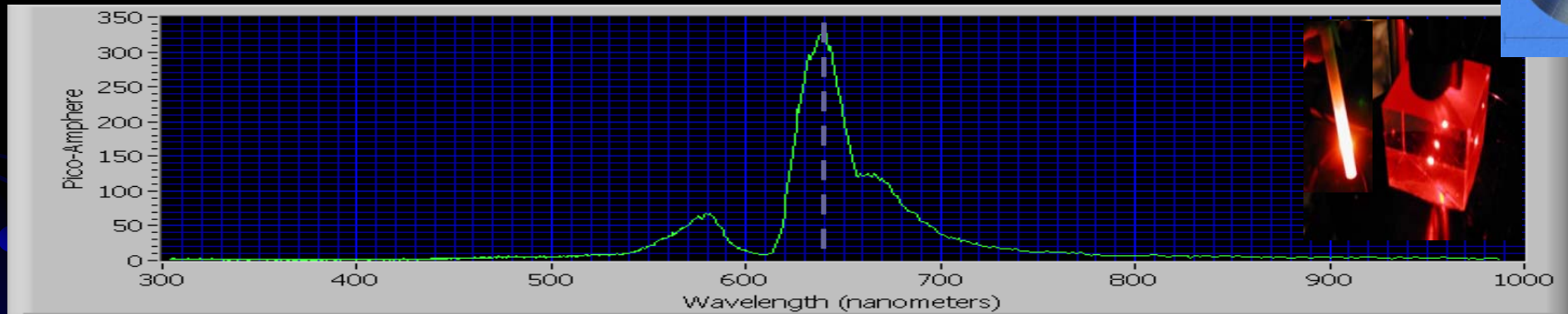
Spectral scans:

Circular Grating: 100 rings, 757 μm diameter
Aperture: 10 μm diameter

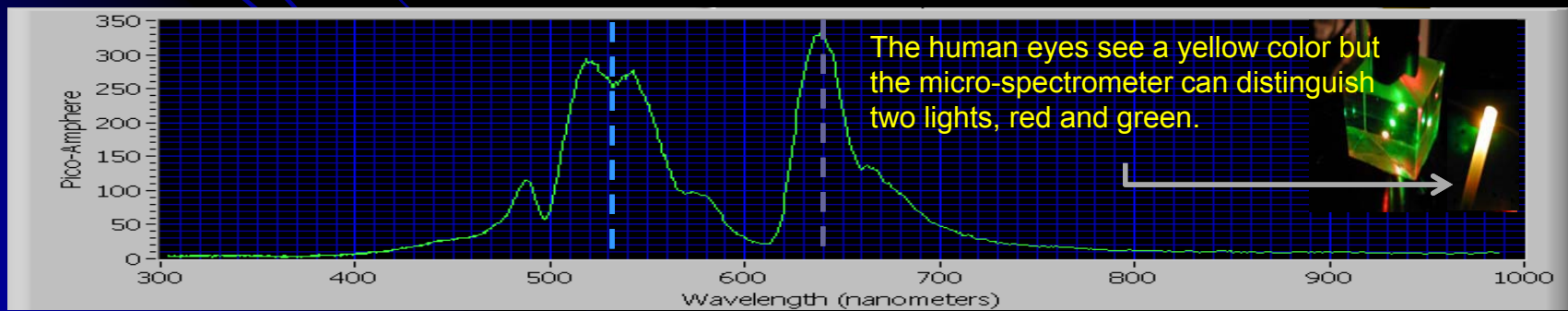
Green Laser: 532nm



Red Laser: 633nm

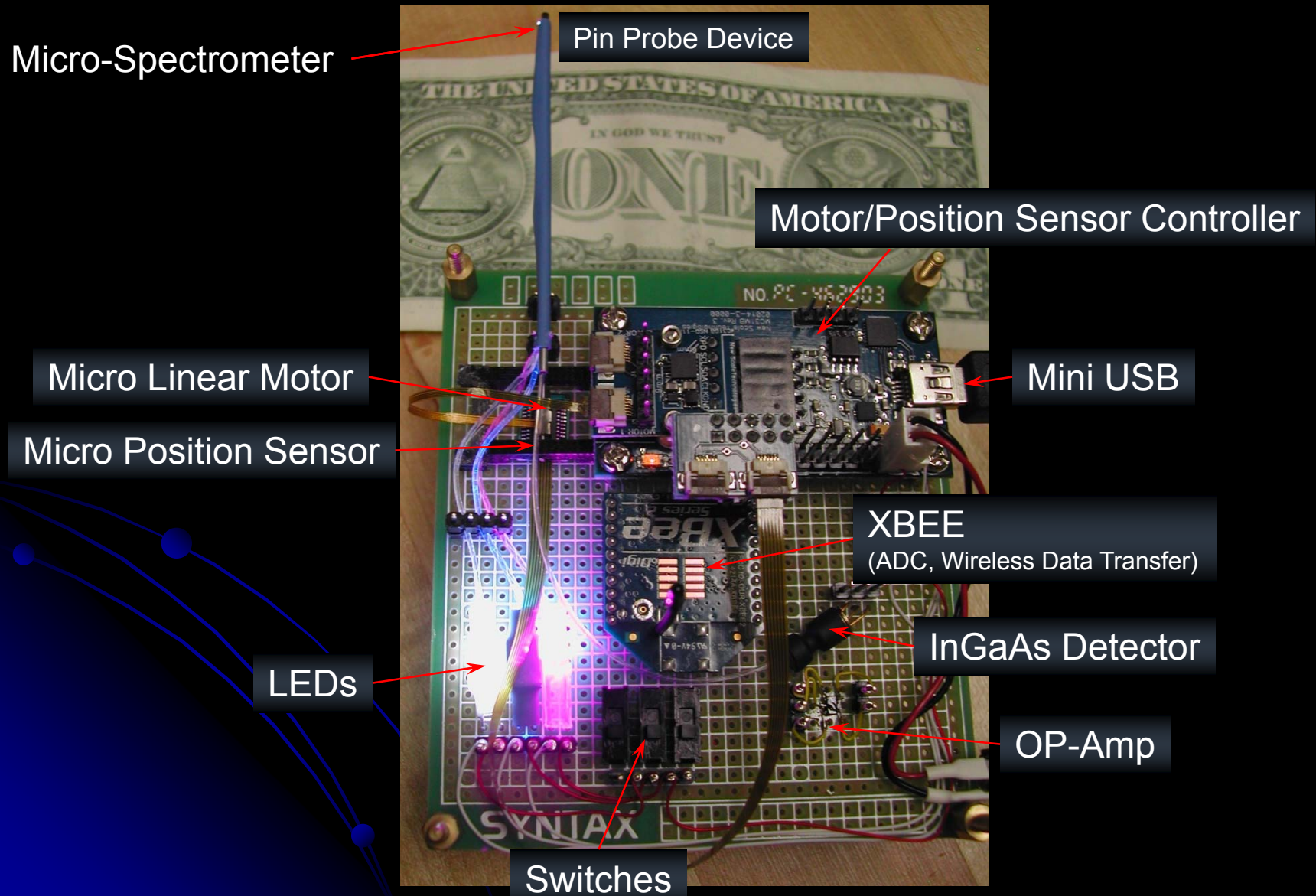


Green & Red Lasers: 532nm & 633nm

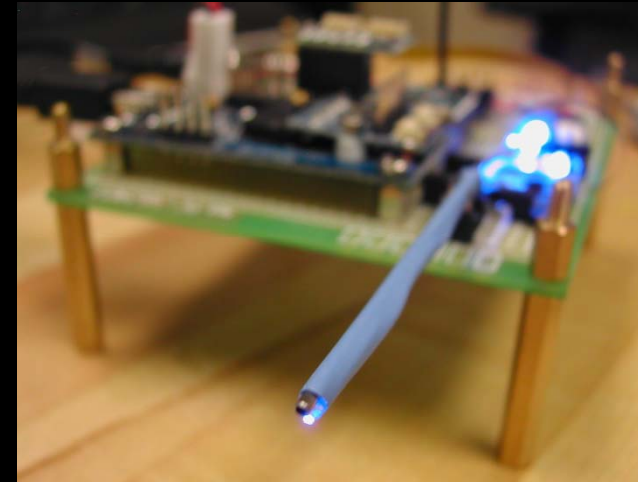
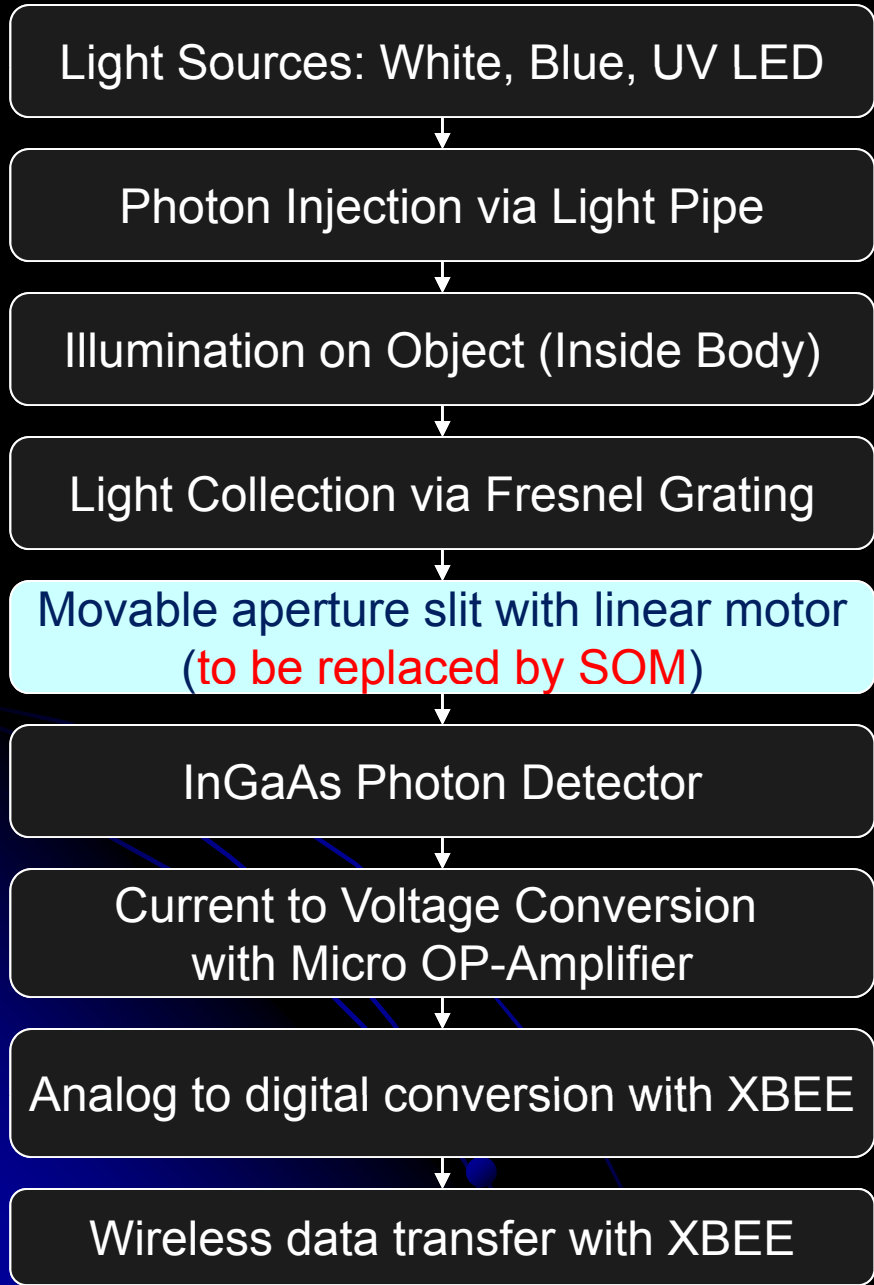




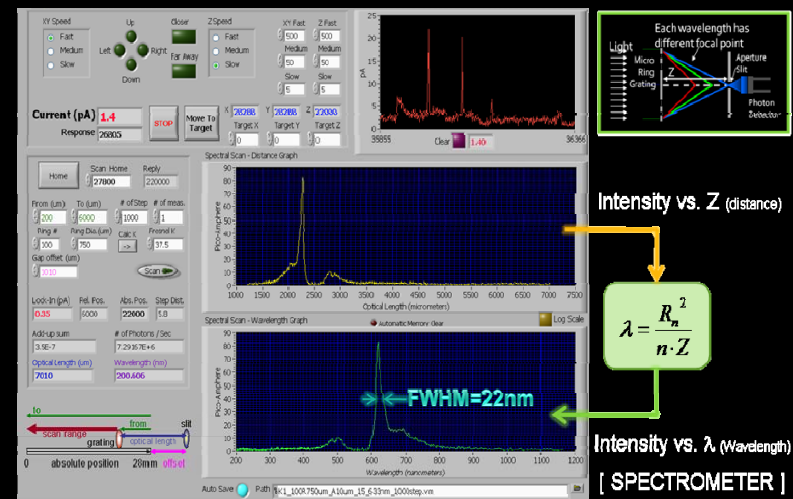
Micro-Spectrometer Component Test Platform

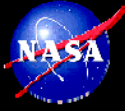


Configuration Diagram



Computer

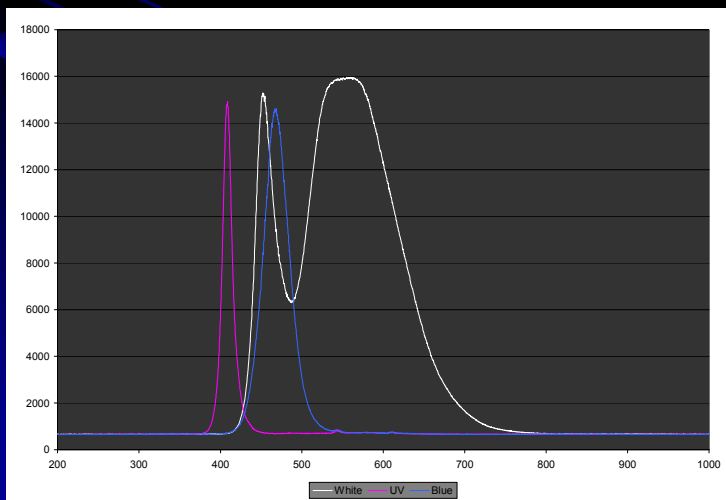




Micro-Spectrometer Component Test Platform Parameters

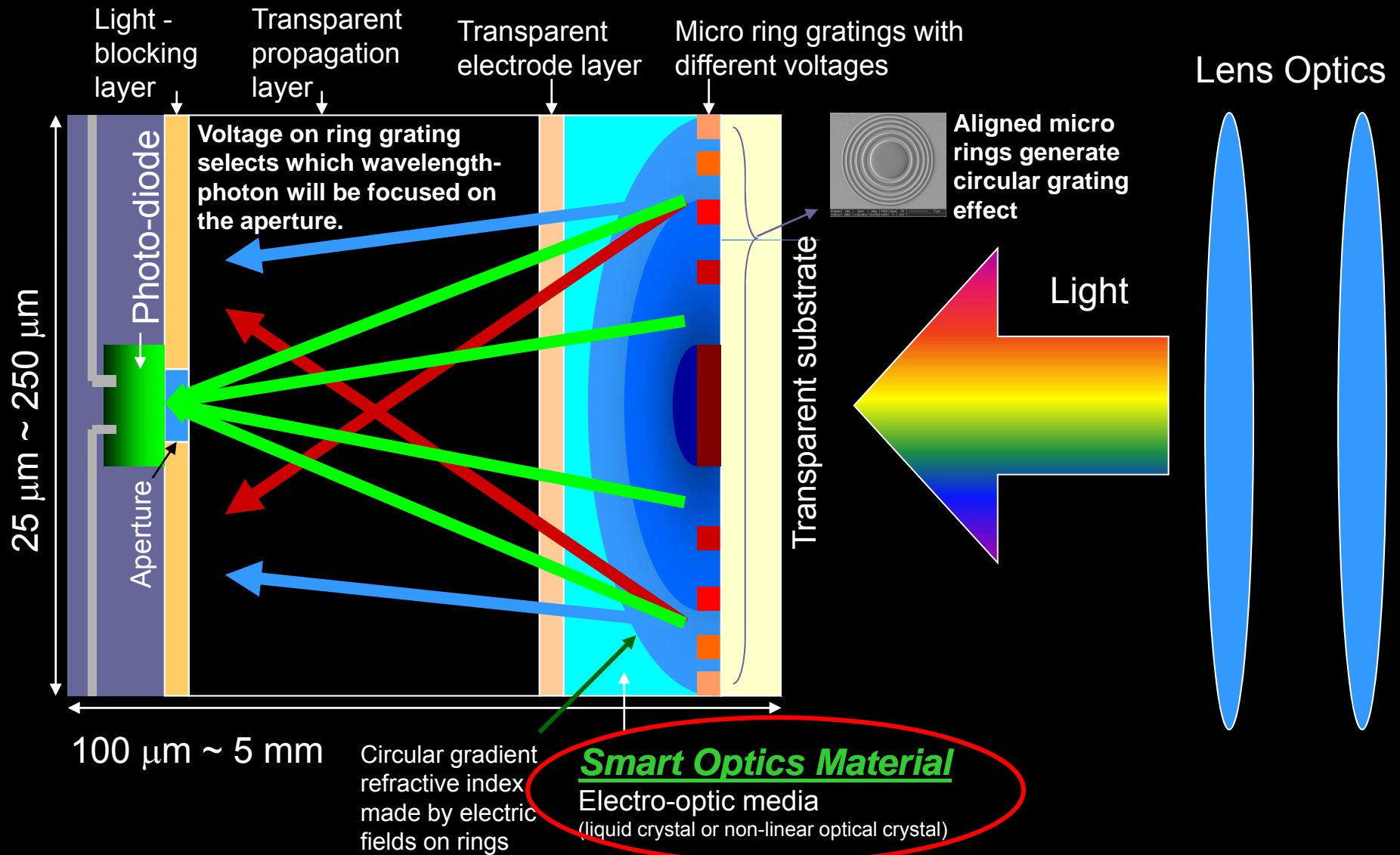


- Light Sources: White, Blue, and UV LED
- Integrated Light Pipe Design: Diameter = 3mm
- Micro Linear Motor: Travel Distance = 6mm
- Magnetic Micro-Position Sensor: 2 micrometer resolution
- Photo Detector: InGaAs Photo Diode
- Mini OP-Amplifier: Gain (V/I) = 10^7
- USB/Serial Interface to control linear motor
- Power: 3.3V, 1.8A max
- ADC & Wireless Data Transfer: XBEE Chipset (ZigBee Network)

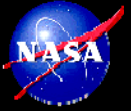




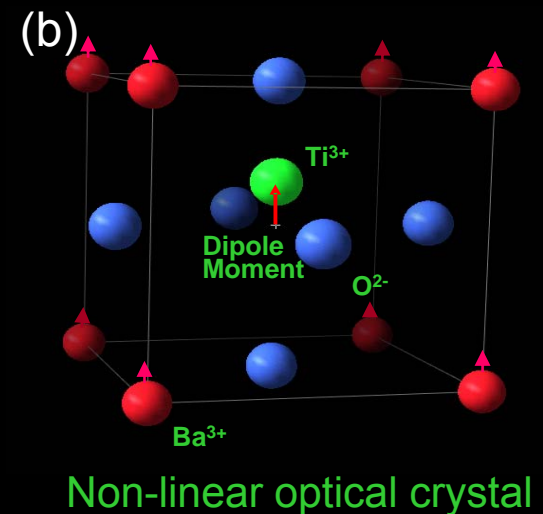
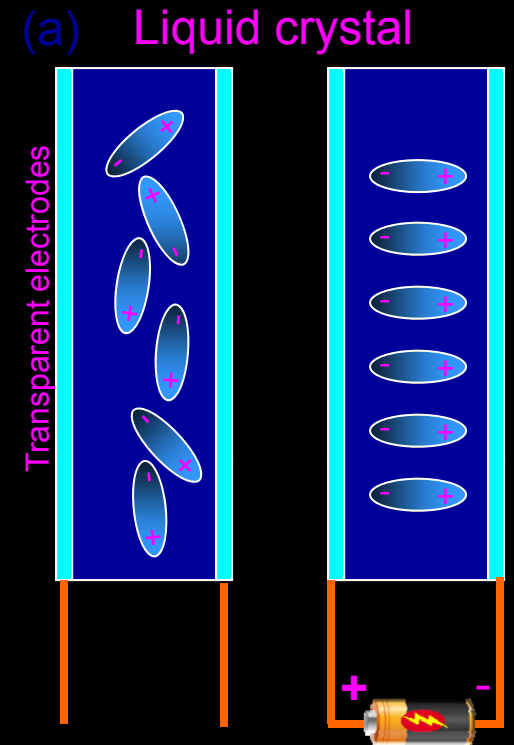
μ -Spectrometer Development Plan



Smart Optics Materials

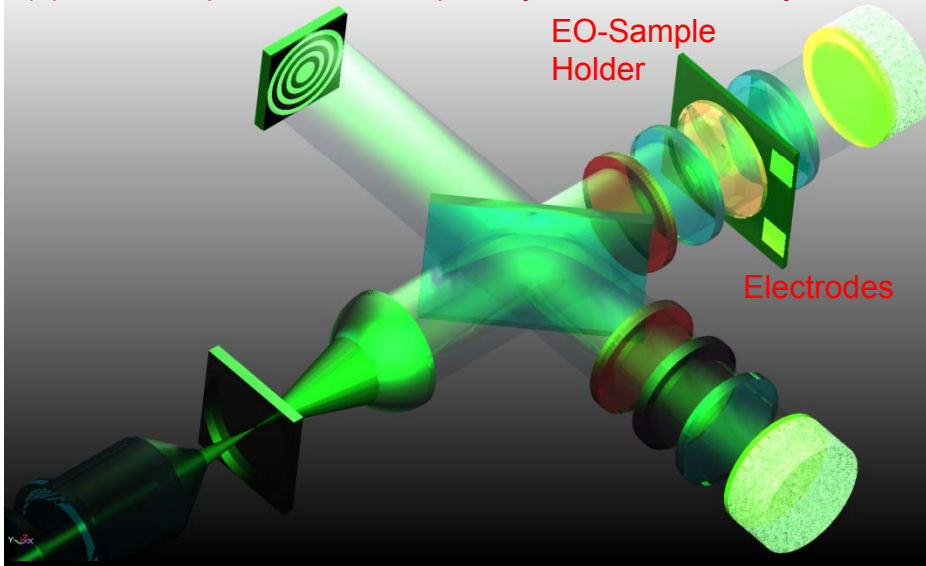


- Smart Optics Materials (SOM) are new optical materials that can control deep properties (intensity, phase, polarization, coherence) of passing light, including
 - electro-optic materials (non-linear optical crystals, liquid crystals, electro-optic polymers)
 - magneto-optic materials (Faraday Effect and Kerr Effect),
 - electro/thermo-chromic materials
 - chemicals that induce refractive index changes
 - optical materials that depend on temperature and pressure
- New prototype SOM characterization system with advanced software is under development at NASA LaRC.
 - Intensity, phase, and polarization of passing lights through many new optical materials while applying various physical/chemical quantities on the materials.
 - A miniaturized compact system has USB interface and exchangeable components for various R&D and commercial applications.
 - This innovative versatile SOM characterization system and characterized optical materials will be used for complete micro spectrometer system.
 - Commercialization of this system accelerates development of new optical materials and devices.

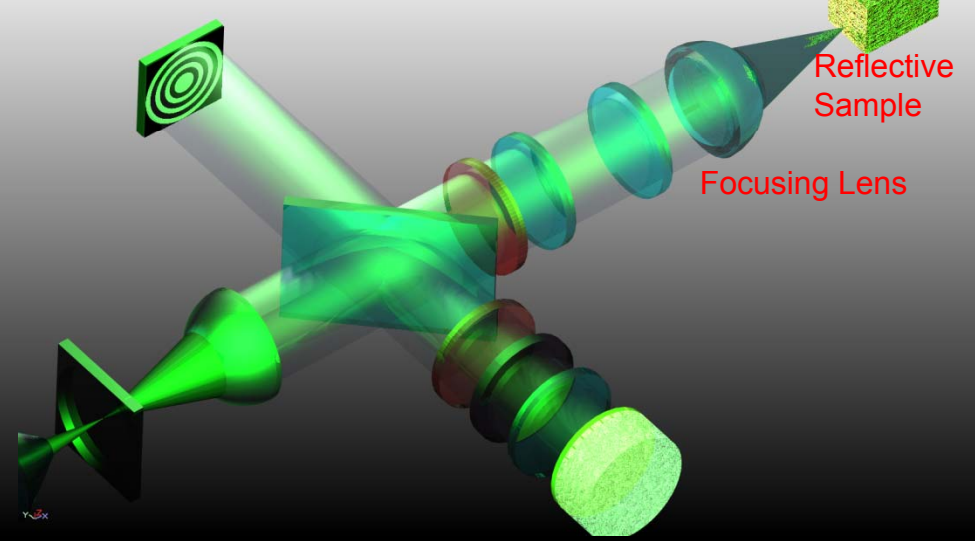


Smart Optics Material Characterization System

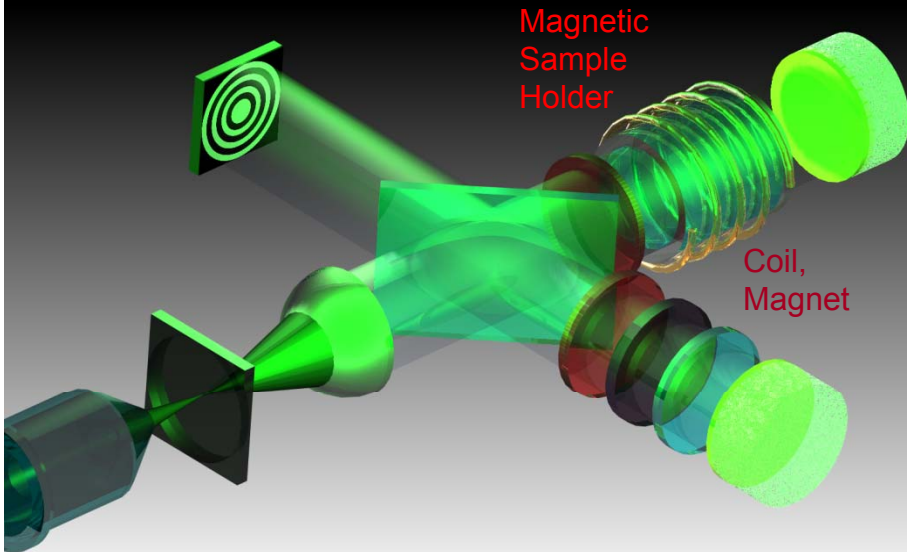
(a) Electro-Optic Materials: liquid crystal, non-linear crystal



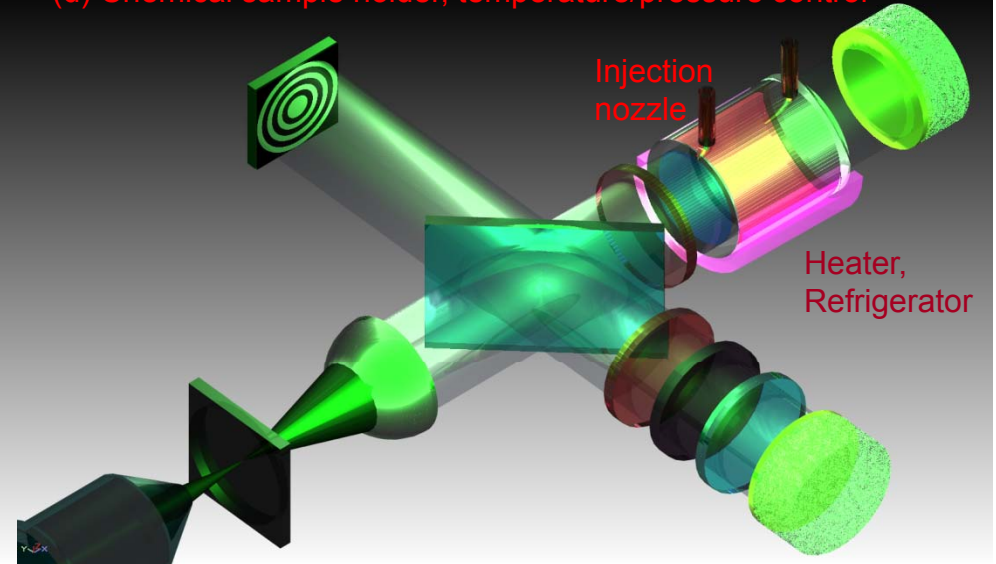
(b) Reflective samples: MEMS device, piezoelectric actuator materials, thermal expansion coefficient measurement



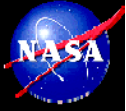
Magnetic Sample Holder



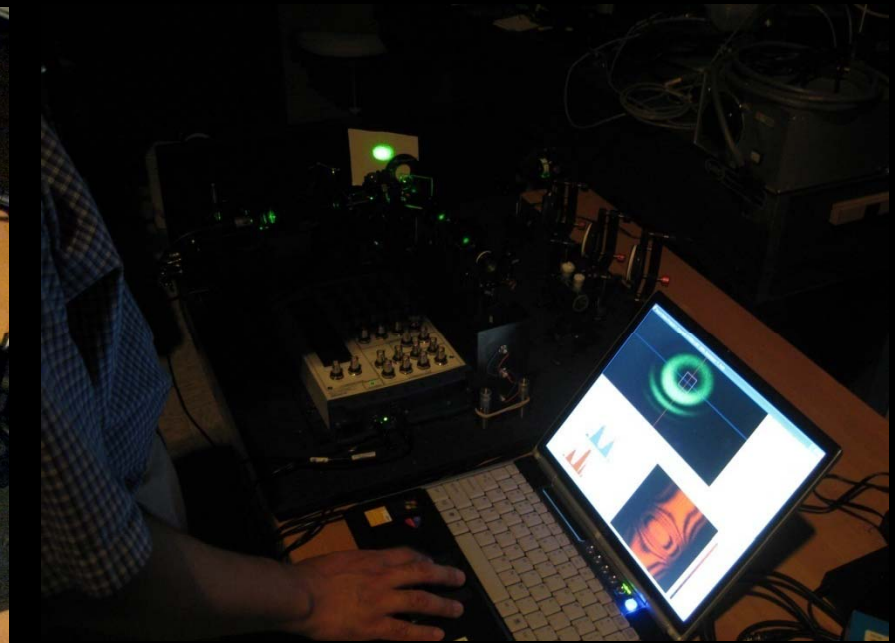
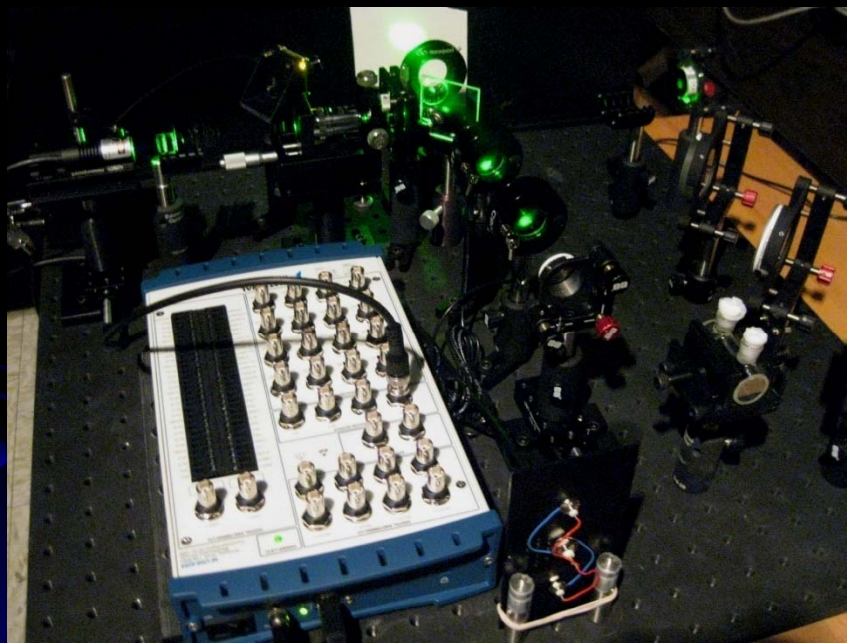
(d) Chemical sample holder, temperature/pressure control



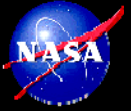
(c) Magneto-optical materials: Kerr effect, Faraday effect



Smart Optics Material Characterization System



SOM Characterizer Software



Show Cursor
 White Color
 Display Time
 Display Voltage

Camera Control **Advanced**

Connect Stop Exposure (ms): 4.8
 Disconnect 1 Frame

Quit

Point Intensity Chart

X-Axis: Voltage (mV) Time (mS)

Line Map Histogram

Photon Distribution at Cursor Lines in Single Image Frame

H	2	2	2	2	2	3	3	3	3	2	3	3	2	3	3
V	21	22	25	34	33	30	33	39	44	44	39	37	38	34	29

Dynamic Map Histogram

Dynamic Photon Intensity Phase Map

X: Pixels/2, Y: Measurement Frames

Linear

Start Volt. End Volt. # of Steps
 -10.0 10.0 500

Start Delay(ms) Delay/Step(ms)
 1000 0

Scan

File Setup Line Map Dynamic Map

Copy Bitmap Save Bitmap Save Data

Color Table: #Step Gamma
 Red 10 1.0

Phase: 0° 170° 180° 85°

Phase Map Data: leLC_-10_10V.rtf

MS Excel can not read more than 255 columns
 Reduce # of Steps below 255 to work on Excel

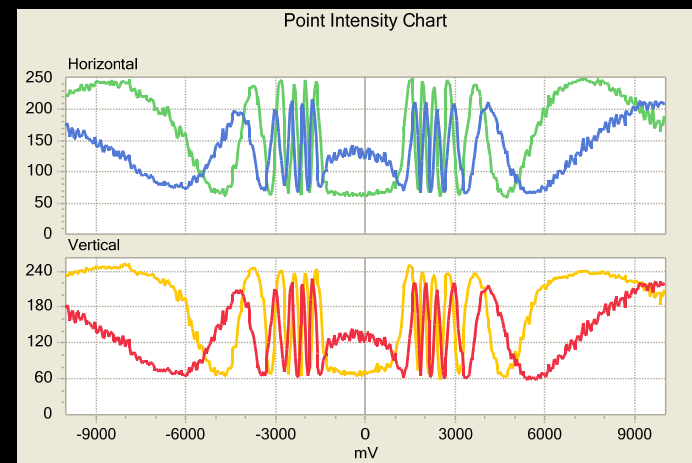
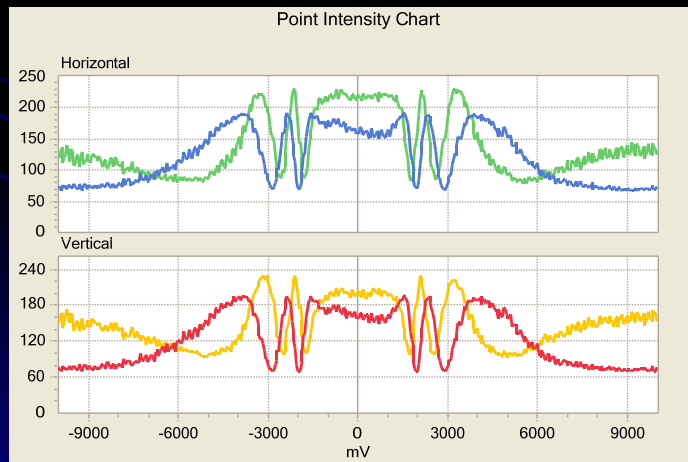
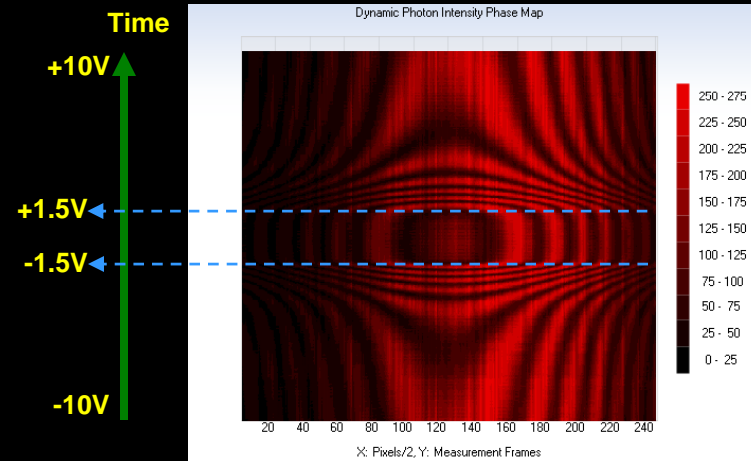
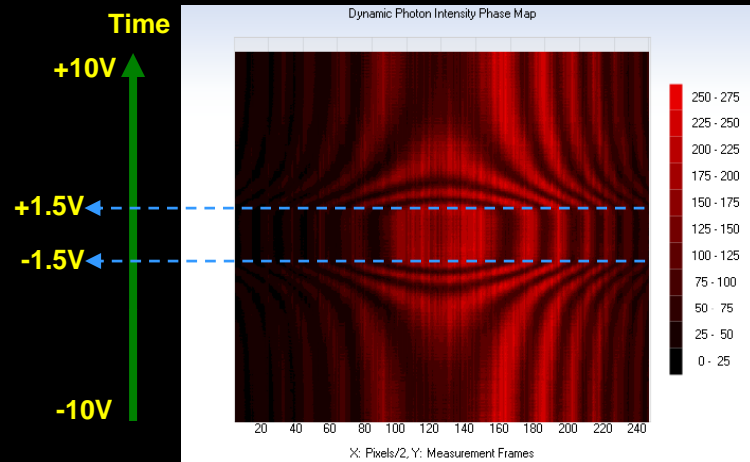
Out1: 0.000 V In1:

Out2: In2:

Progress: | Cursor (418,241) | Offset (469,289) [51,48] | Mouse (693,26) | Ready



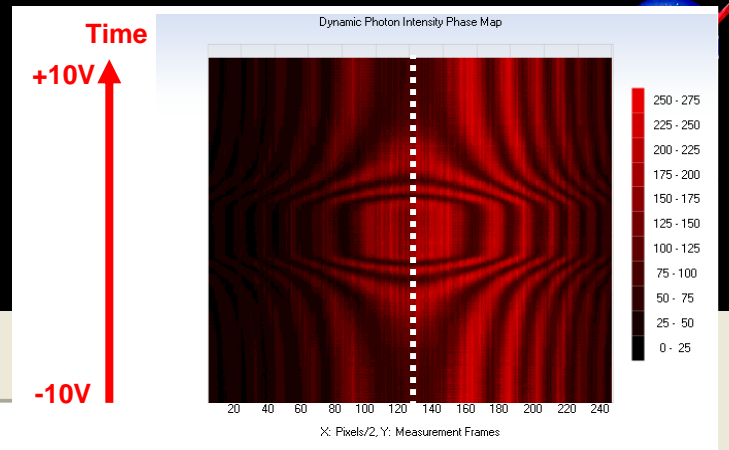
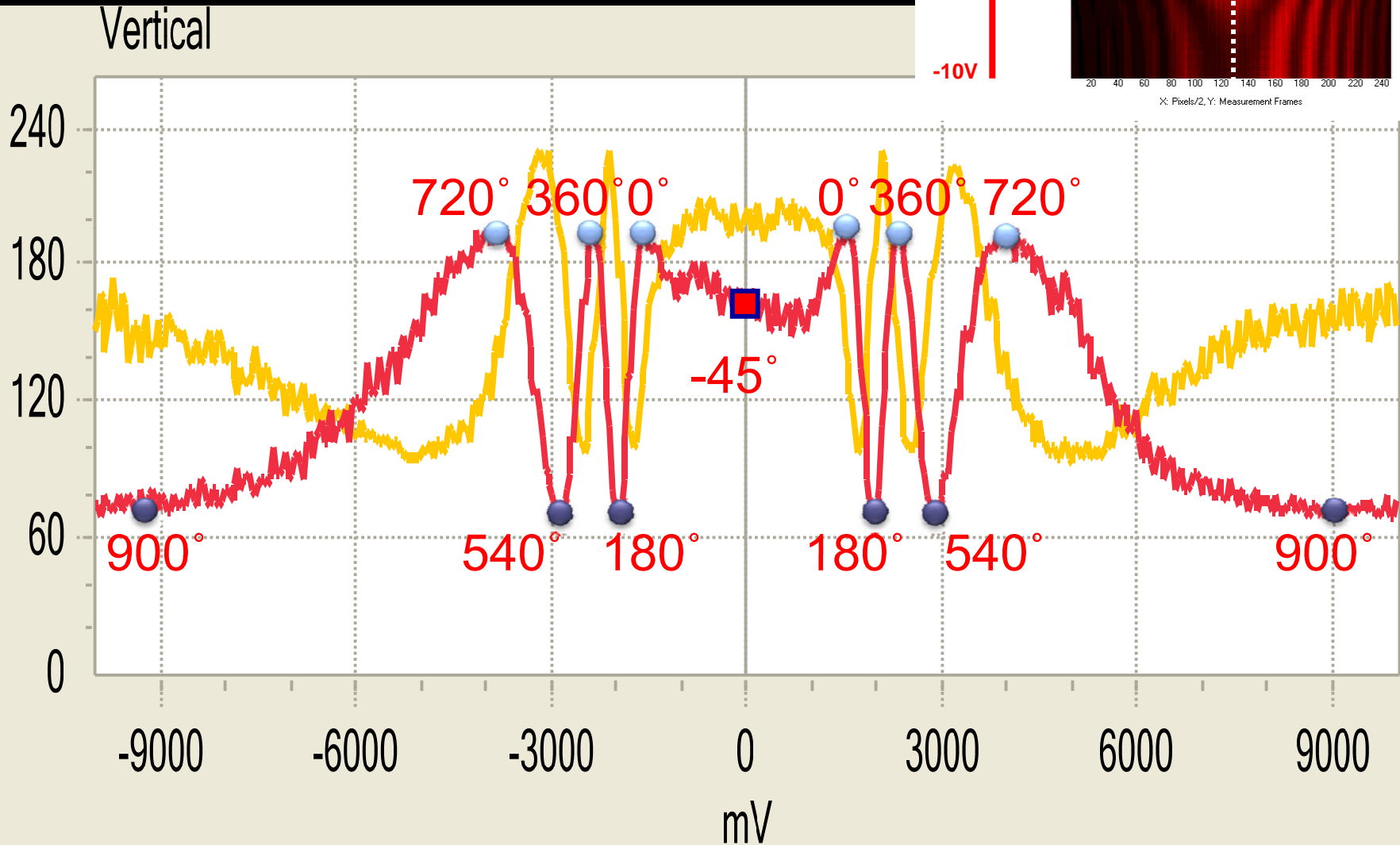
Dynamic Phase Map Analysis



Liquid Crystal Single Layer

Liquid Crystal Double Layer

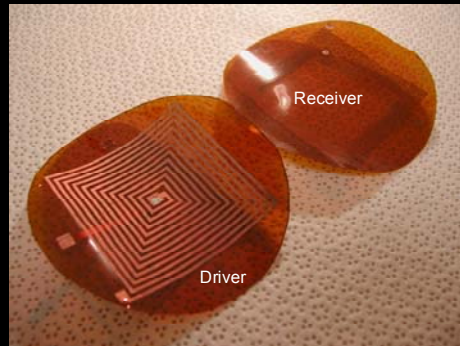
Phase Angle Measurement





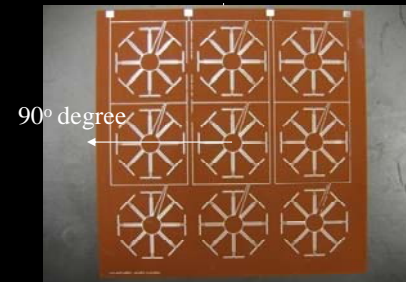
Mobile Wireless Power Transfer with Micro Coil and Microwave

Micro Induction Coil (MIC)

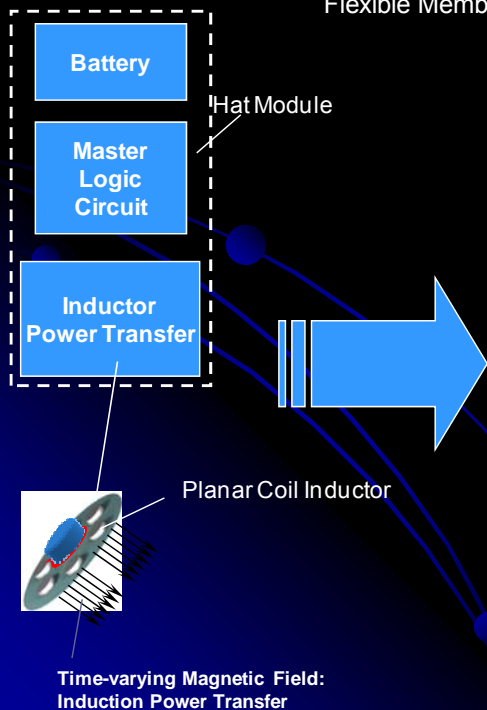


Flexible Membrane Inductor

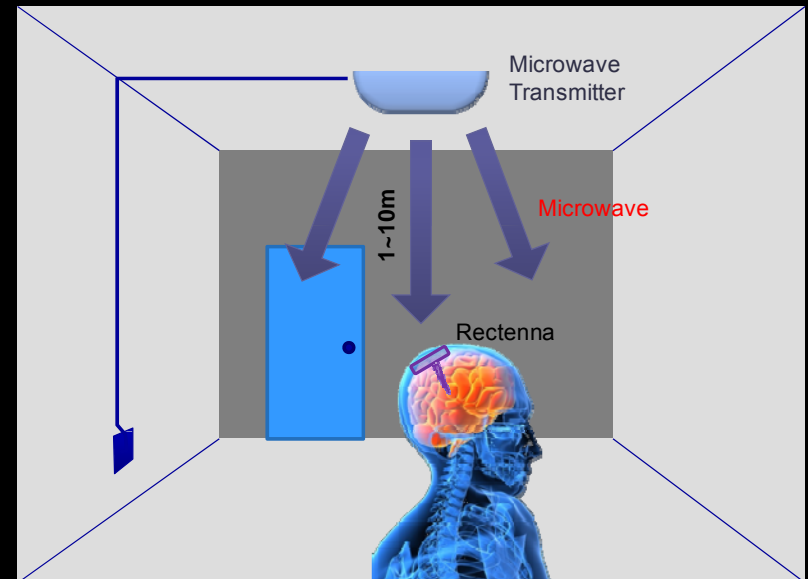
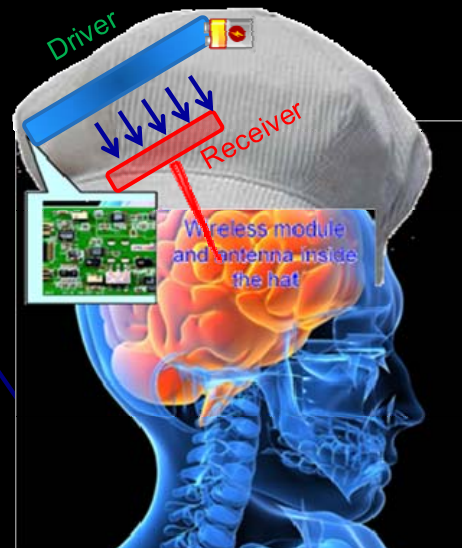
Thin-Film Rectenna Array (TFRA)



3 x 3 flexible rectenna



Short Range (1~10cm) Solution

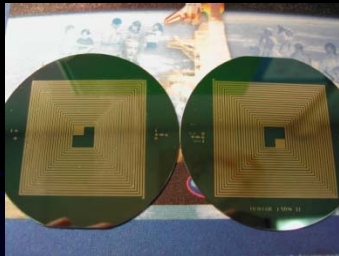




Wireless Power Transfer

Inductance Power Transfer

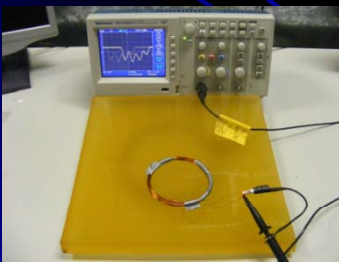
- 0-3 cm, short range
- Safe for human interaction
- low power applications



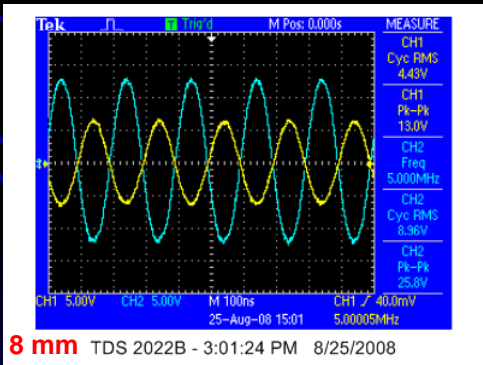
Planar Coils



Coil powering an LED



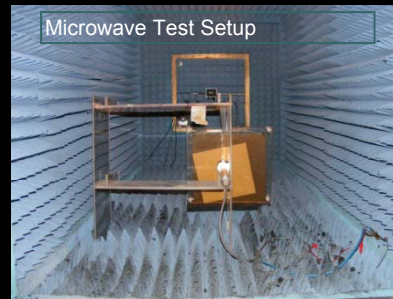
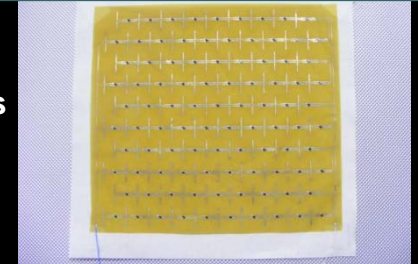
Coil Test Setup



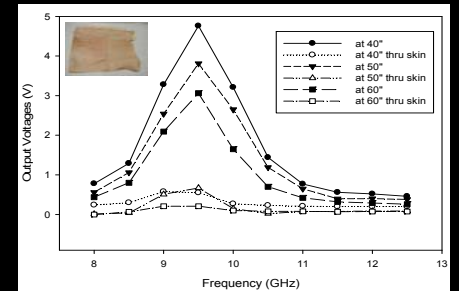
Microwave Power Transfer

- 1-1000 m, long range
- Low to high power applications

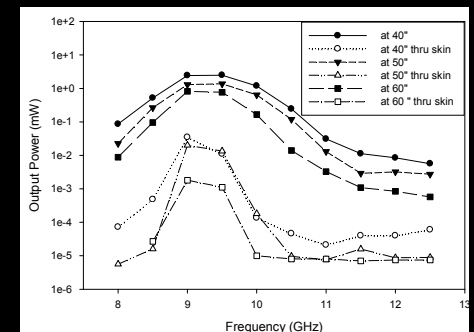
Thin-Film Rectenna Array (TFRA)



Flexible Rectenna Array

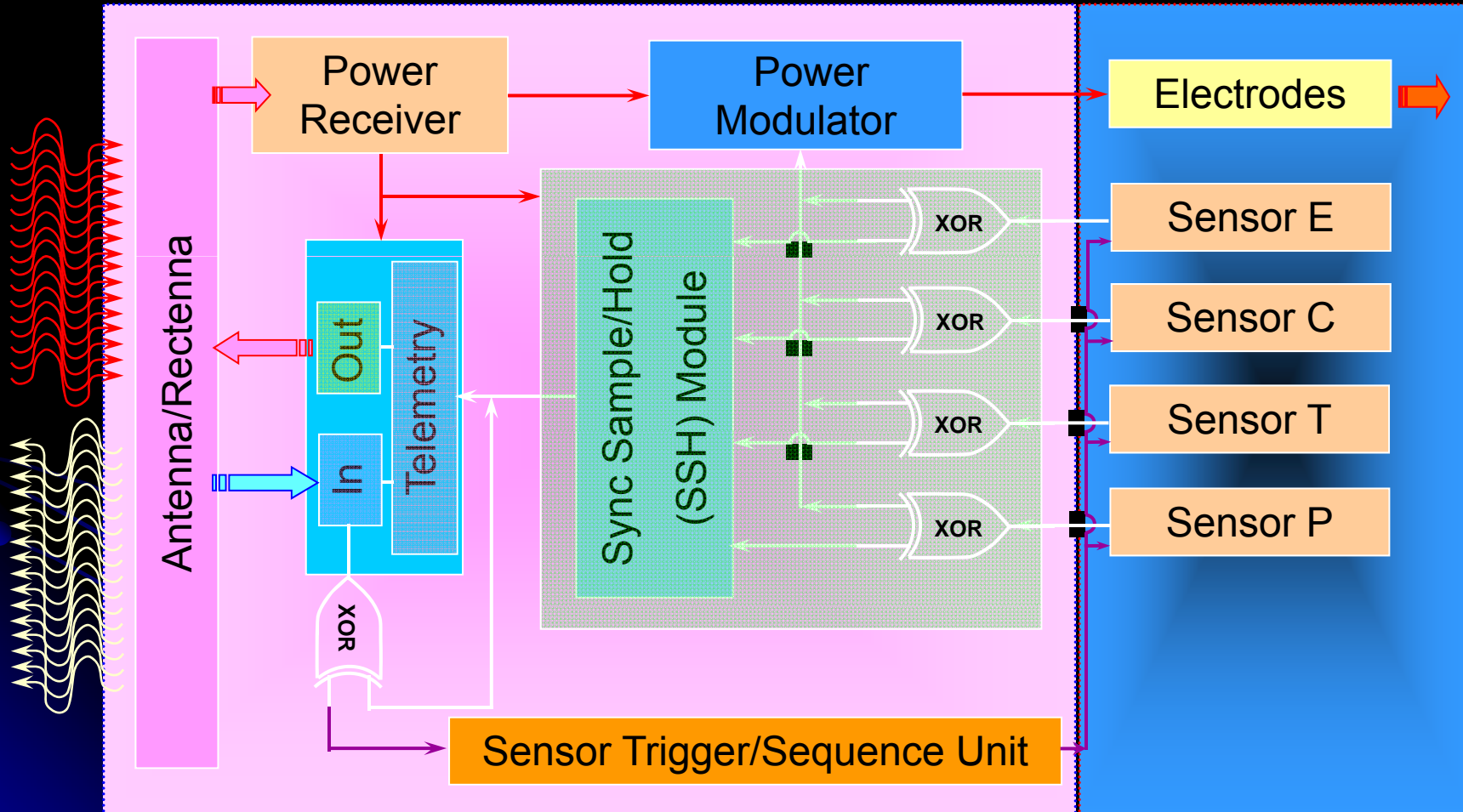


Microwave Generator and Amplifier

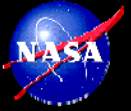




PPD Logic (internal) with TFRA or MIC

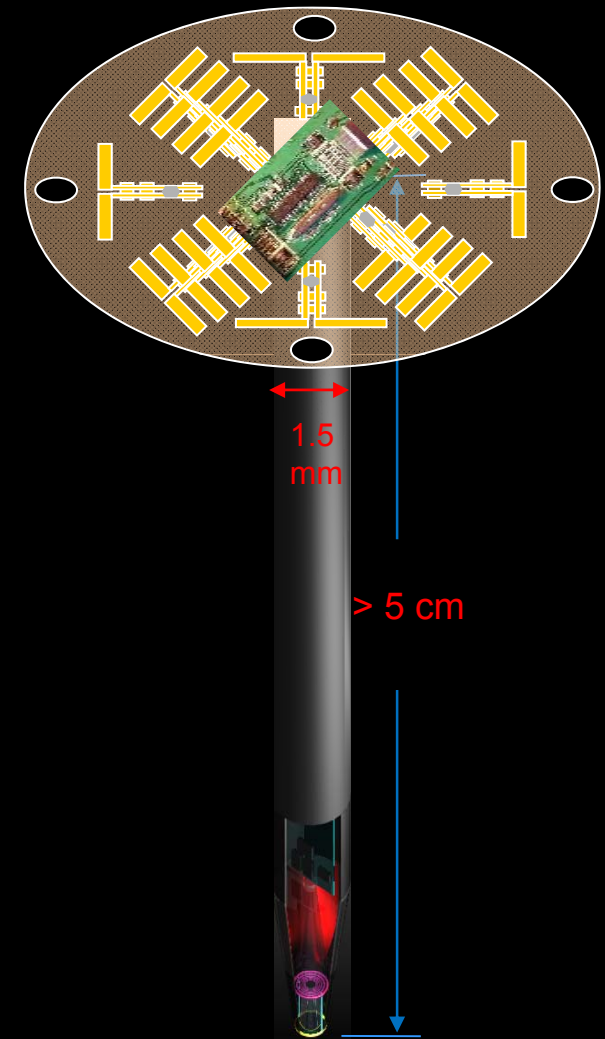


Wireless



Features of Probe Pin Device

- Selection of Targeted Spectral Line for μ -SM:
 $600 \text{ nm} < \lambda < 1000 \text{ nm}$
- Spectral Resolution: $\leq 10 \text{ nm}$
- Downsize of Micro-Spectrometer:
 $< 2 \text{ mm}$
- Platform Design for Other Sensors Integration:
 ρ , T, V, and chemicals
- Wireless Power Feeder and Integration:
both MIC and MW
- Telemetry Circuit and Test with Skin Tissue:
FM mode
- Chip-scale Design of Electronics:
Miniaturization





Summary

- Neural Sensing Probe Pin Device with micro-spectrometer is under development.
 - Micro Spectrometer Component Test Platform was set up.
 - The world's smallest optical path volume (1mm^3 was achieved with 0.75mm diameter.)
 - This is $1/1000^{\text{th}}$ volume compared with today's smallest commercial spectrometers (1cm^3)
 - Demo model developed with actuator-controlled focal length as a stop-gap approach
 - All basic electronics for sensor, telemetry, and power coupling were fabricated, but required chip-scale miniaturization
- Prototype SOM characterization system is developed to measure **intensity, phase, and polarization** of passing lights through many new optical materials while applying various physical/chemical quantities on the materials.
 - A miniaturized compact system has **USB interface** and **exchangeable components** for various R&D and commercial applications.
 - SOM system and software are **Tech-Transfer ready**
- Wireless Power Transmission test using polyurethane layers and pig skin was satisfactorily performed.
 - MIC was proven to be effective for short range power transmission, like a hat system
 - TFRA was effective for short (near-field capacitive coupling) and long (far-field) range power transmission.