GE Research & Development Center

Industrial development & applications of UV photonic systems

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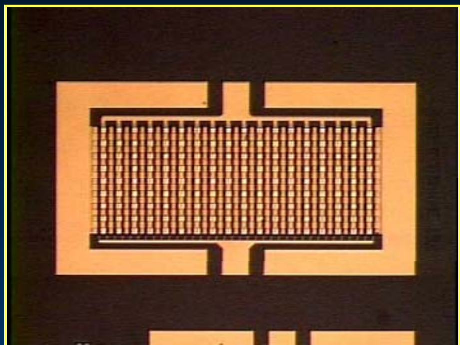
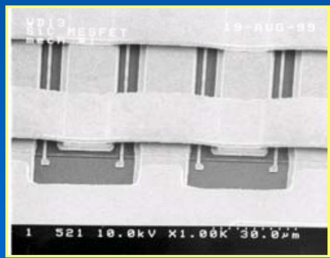
Microwave Devices



SiC and GaN Microwave Programs for Lockheed Martin
Phased Array Radar

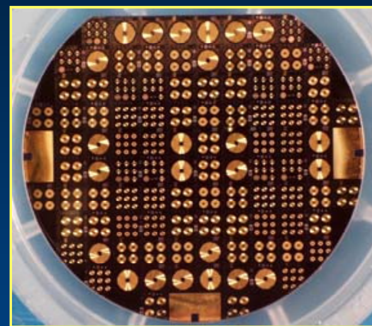
- High Voltage operation (2× Si, 4×GaAs)
- Simpler Phased Array Prime Power Distribution
- High Temp. operation (2× Si, 3× GaAs)
- Much higher Transmitter Power (3× Si, 10× GaAs)
- Simpler cooling



•SEM of SiC MESFET Built on 1 3/8" Wafer

Power Devices

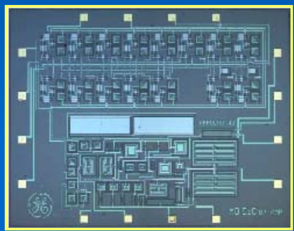
•4000 V, 5 A PiN SiC Diodes
•350 °C Package
•Fast switching and small reverse recovery time



- High Temperature, high voltage diodes (GEAE, GEMS, GEL)
- High V (600-1200 V) switches (GEL)
- LM pulsed power (E-gun)

Future Integration Capabilities

Chopper stabilized SiC op amp



Optoelectronic Devices

GELcore Produced LED's
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SiC Flame Sensors
•Gas Turbine Flame Tracker

AlGaN-photodiode sensor system

SiC UV photodiodes

GE SiC Flame Sensor for Gas Turbines

- Produced by GE Reuter-Stokes
- First Commercially Used SiC Device

Advantages

- 10x the sensitivity of Geiger-Mueller sensors
- Low voltage operation
- Fast response time
- Wide dynamic range to track flame dynamics
- Reduces Turbine costs by $1M/Turbine

Volume
- 6,800 devices installed in turbines
- 15,000 shipped by year end

System Integration Challenges:

1) Material

- Development with CREE
- Theoretical Design Work
  - Tailor epitaxial layers
- Uniformity
- Dark Current
- Dual (CREE/ CRD) Processing

2) Packaging

- Sensor signal processing
- High impedance feedback circuit
- Ceramic vs. glass headers
- Thermal Cycling

3) Qualification Procedures

- Vibration Tests
- Centrifuge Tests
- Thermal Cycling Tests

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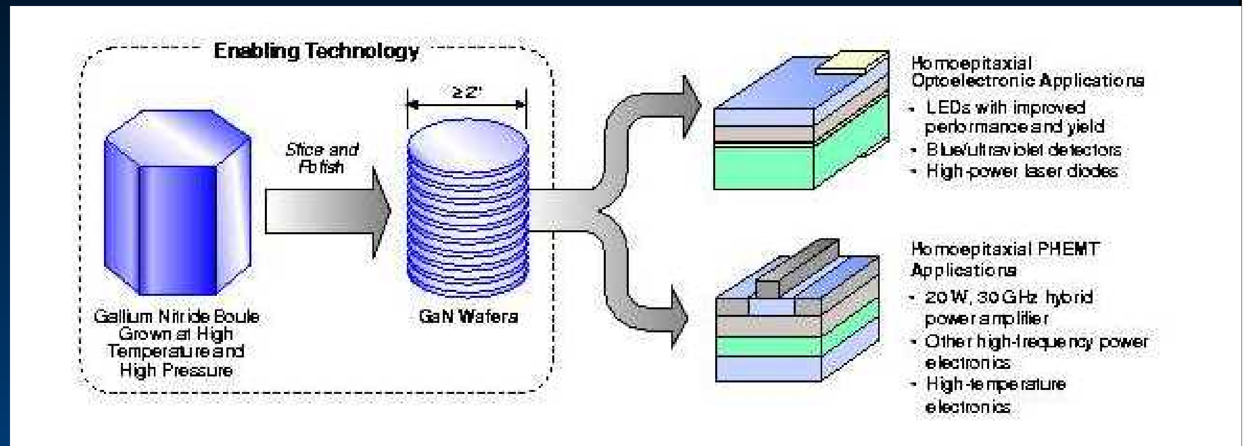
NIST ATP: Bulk GaN and homoepi device mfg

• Project Objective

✓*Develop technology to manufacture 2" GaN wafers to support burgeoning industry*

- ✓ *Quantify performance in state-of-the-art homoepitaxial devices (LEDs, high-frequency amplifiers)*



Core Innovation

- **Link GE high pressure technology, growth chemistry for GaN**

Key Technical Challenges

- **Adapt growth chemistry to high-pressure cell**
- **Scale GaN crystal size up to 50 mm**
- **Quantify device performance advantages**

JV: GE Corp. Research & Development; Sanders. Subcontractor: Cornell University
ATP Project Number: 99-01-2069
Project Start/End Dates: 11/1/99-10/31/02
ATP Project Manager: Elissa Sobolewski

NIST ATP: Manufacturable solid state lighting

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Conventional encapsulation epoxy absorbs blue and uv light, resulting in yellowing and light loss in packaged LED's (e.g. Osinski & Barton)

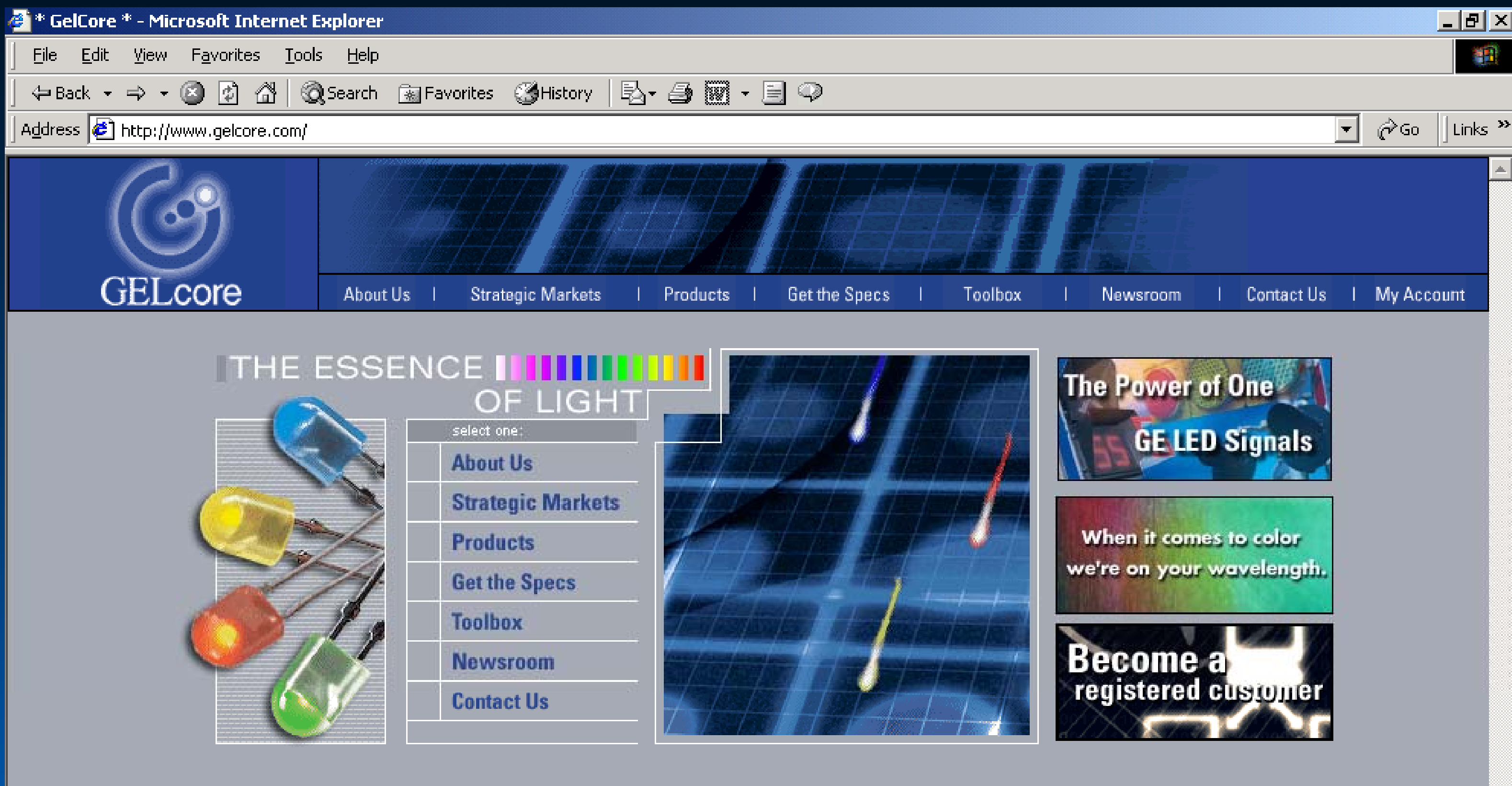
Conventional epoxy after 600 hrs UV aging

CRD UV-resistant epoxy after 600 hours UV aging

Encapsulation development will be more challenging for deep UV LED's

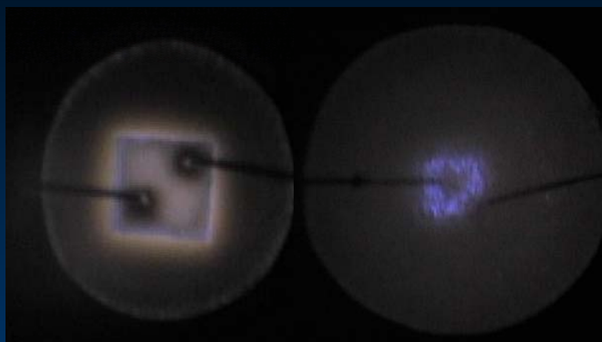
NIST ATP: Cree Lighting: InGaN LED's
GE CRD: Phosphors & encapsulation

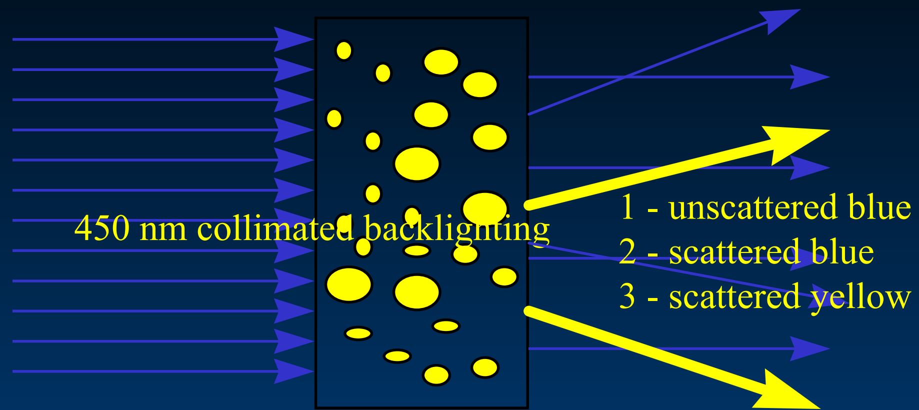
GELcore

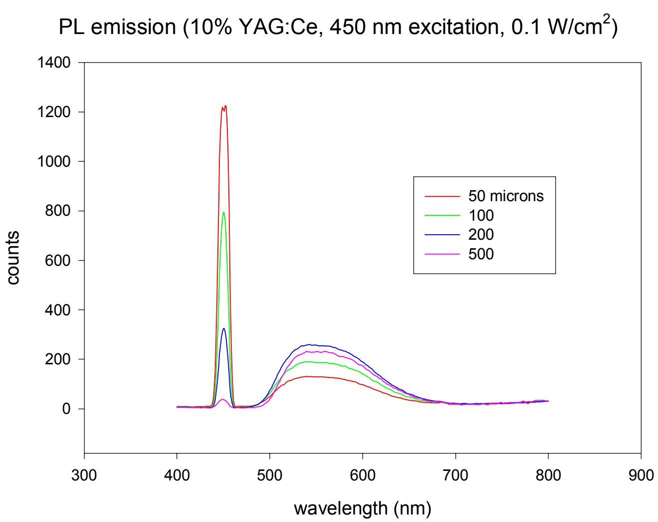


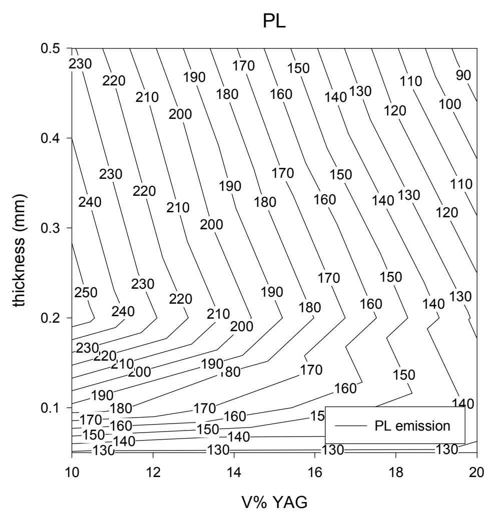
GELcore JV: 51% GE Lighting, 49% Emcore
Emcore: Epitaxial materials growth
GE Lighting & GE CRD: Phosphors, packaging, reliability

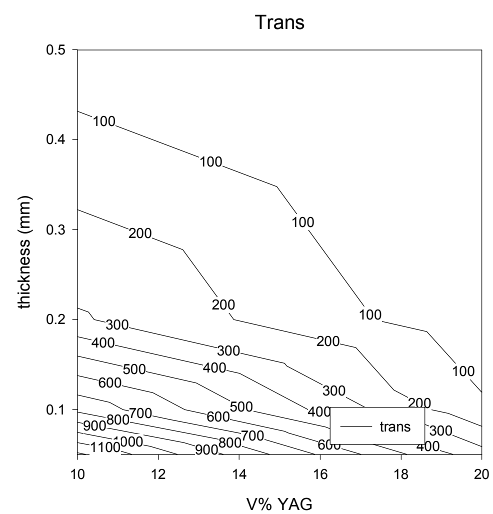
Downconversion: optimization of phosphor layer











For blue LED + YAG:Ce, some blue bleedthrough required to make white

Fiber optic bioprocess monitoring

Fluorescence monitoring of biochemical waste treatment media

Figure 3: Fiber optic fluorescence probe

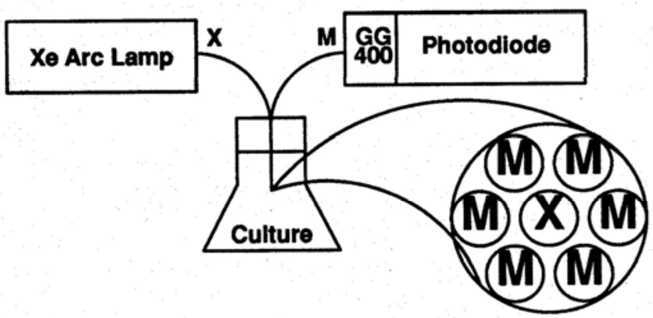


Figure 2: Emission vs. OD: 48 hours p.d./glucose

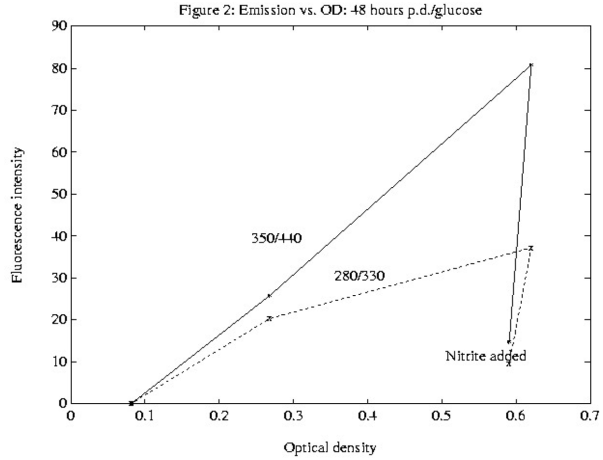
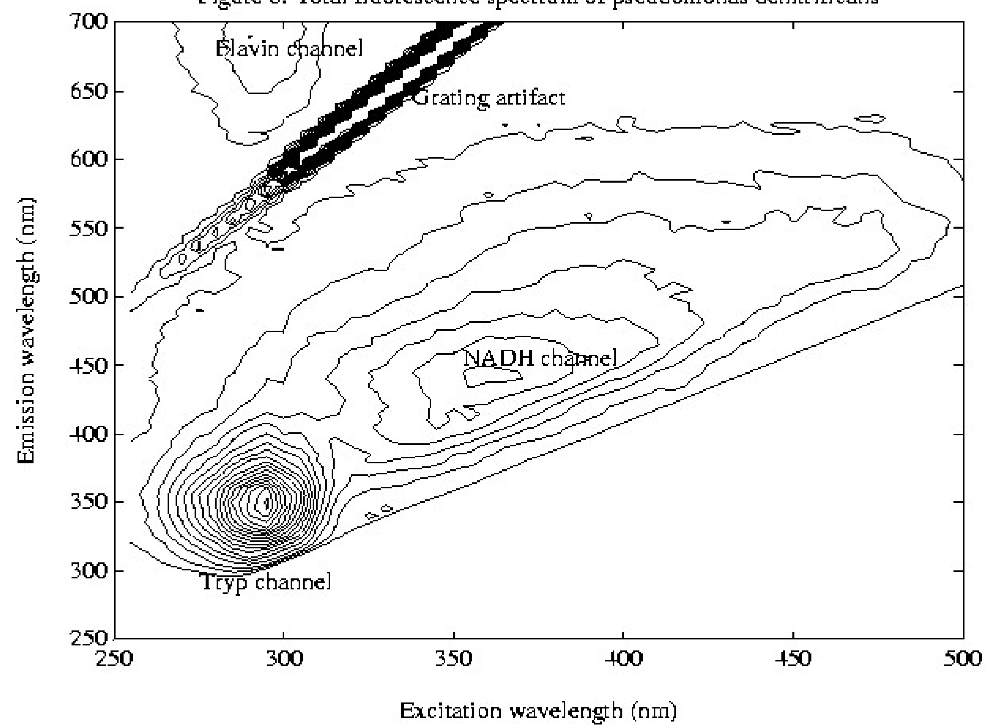


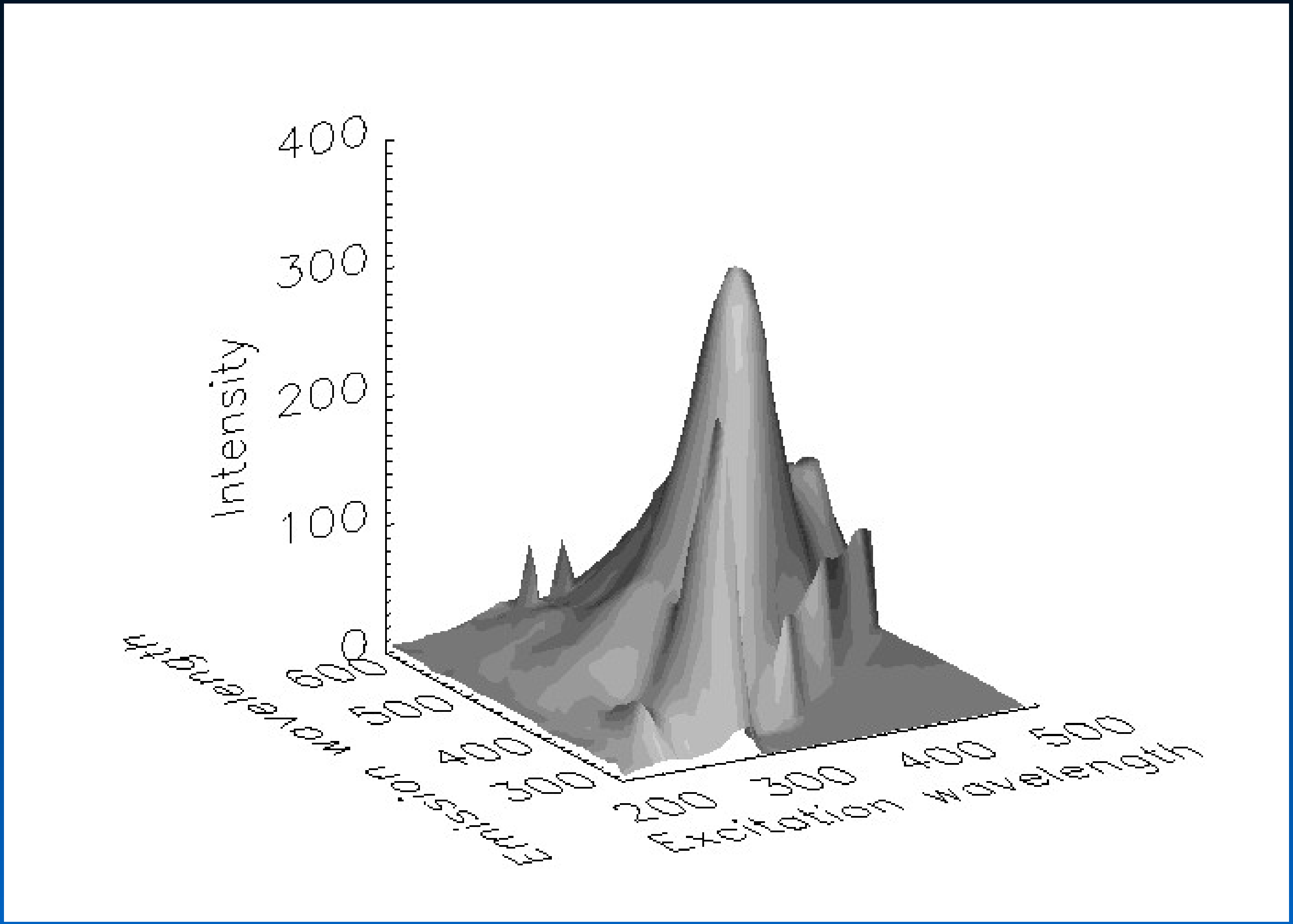
Figure 6: Total fluorescence spectrum of pseudomonas denitrificans



Secondary inner filter effect: tryp emission pumps NADH

Stokes & Uzgiris, (1) Biophysical J, 61 A315, 1992, (2) Proc Intl Conf Env Cont (1992)]

Fluorescence of biological material



Complex fluorescence signature requires post processing

Polymer manufacturing process monitoring

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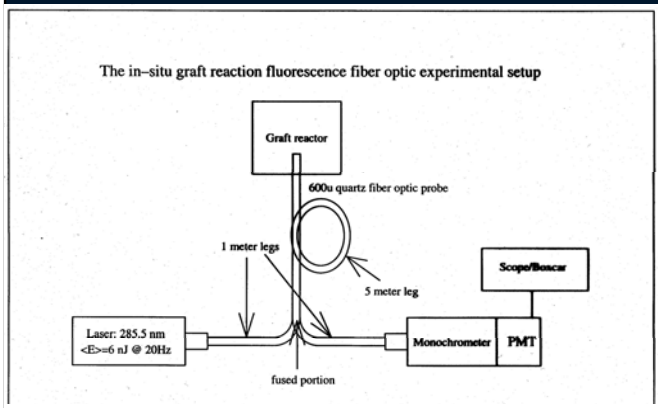
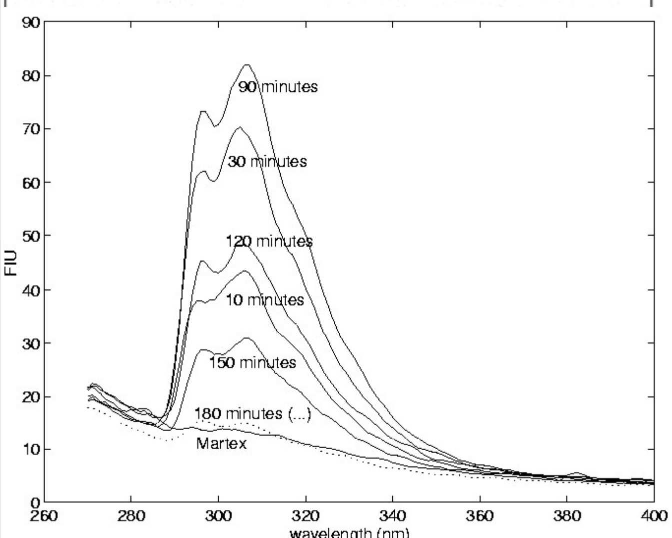
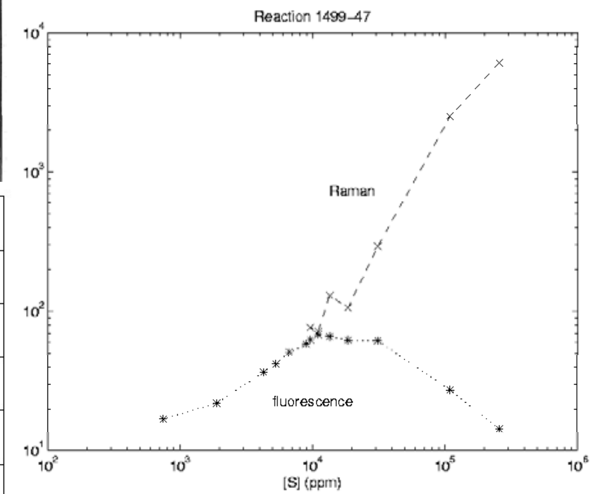
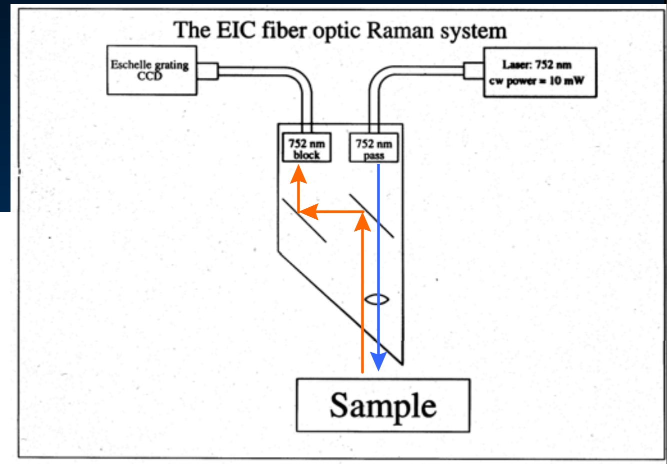
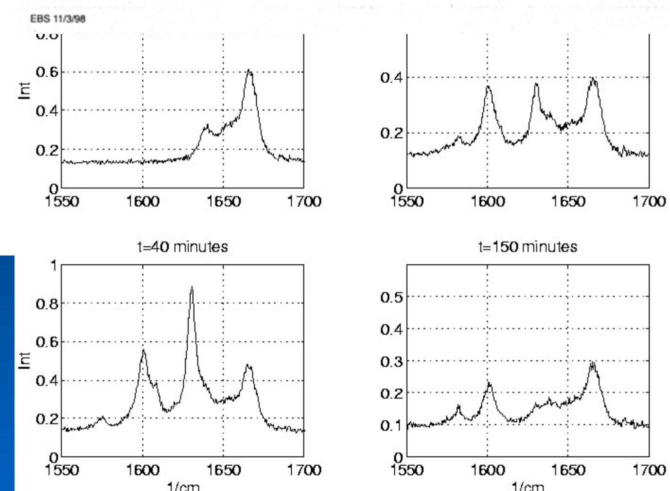
Lab demo of FO monitoring of ABS polymerization









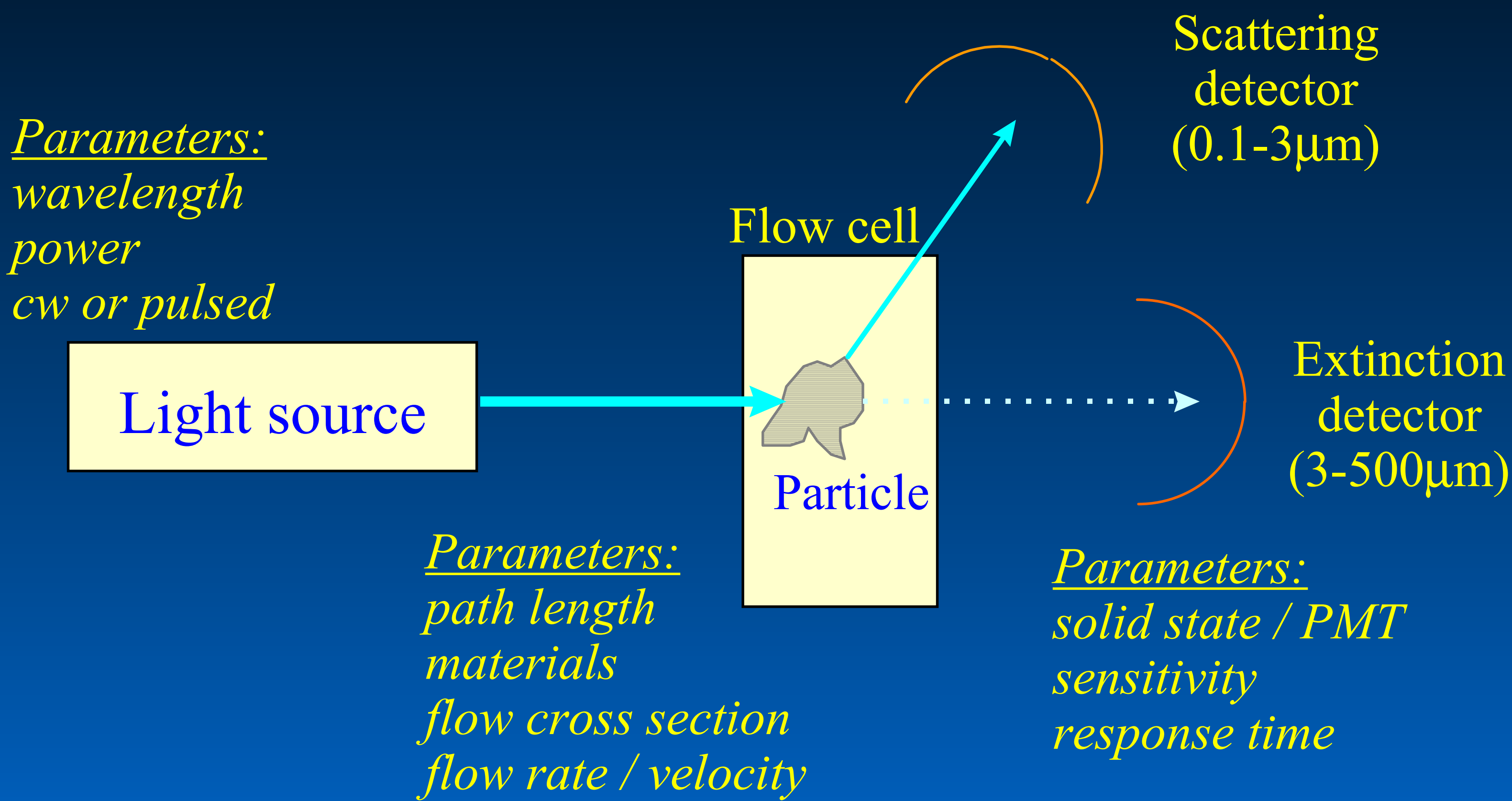


Cheap light sources would enable industrial process process monitoring

Fiber optic probes used to monitor styrene concentration (intensity + lifetime) in ABS polymerization reaction: Raman excited at 850 nm tracks styrene down to 1%, fluorescence excited at 295 nm tracks styrene down to below 1000 ppm [Stokes, Codella, Resue, England, Pattanayak, ECS 1998]

Polymer manufacturing process monitoring

Light scattering used for contaminant counting/sizing in optical polymers



Integration of "flow cytometry" techniques (FLAPS: Fluorescence Aerodynamic Particle Sizer: use UV abs + fluorescence and scattering) would enable classification as well as sizing

Summary

1 – Industrial applications
- A – Chemical and biological process monitoring
- B – Contaminant particle counting and classification in optical polymers
- C – Optical storage ?
- D – General illumination (requires appropriate phosphors) ?
- E – UV water sterilization ?

2 – System requirements for liquids
- A - Reliable packaging: UV resistant polymers
- B - Low cost: (~$100-$1000)
- C - Low maintenance
- D - High reliability (~10,000 hour MTBF)
- E - Relatively low power for fluorescence (~10-100 uW for 100-1000 ppm)
- F - Higher power for Raman (~100 mW for 0.1 to 10%)

3 – General comments
- A - Multiple spectroscopies + light scattering (FLAPS) enhances selectivity
- B – Fluorescence lifetime for molecular interaction info
- C - For airborne material, need either:
  - 1 – Higher power, or
  - 2 – Sample concentrator