

# Faster than the speed of light

## Applications for Cerenkov Imaging

Jan Grimm



## History



Marie Curie

"One of our joys was to go into our workroom at night; we then perceived on all sides the feebly luminous silhouettes of the bottles or capsules containing our products. It was really a lovely sight and one always new to us. The glowing tubes looked like faint, fairy lights."

(Marie Curie, Autobiographical Notes pp. 186-187)

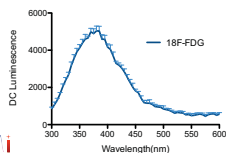


Pavel Cerenkov

"However, a more detailed quantitative investigation of this light process enabled us to find a range of properties so remarkable as to afford incontrovertible proof that here we were dealing with no ordinary everyday luminescence, but with a phenomenon of an entirely new kind; and one of extraordinary interest not only on account of its significance in principle but also in regard to the many practical possibilities for its use."

(Nobel Lecture, Dec. 11 1958; with Frank and Tamm)

## Physics



- When a charged particle travels through a dielectric medium faster than the speed of light in that medium.
- Continuous-spectrum, polarized blue light.
- Emission of electromagnetic radiation

## Physics

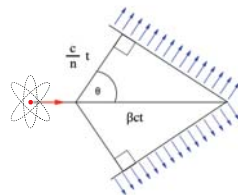
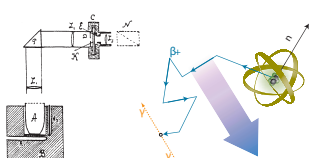


MAGIC Cerenkov telescopes on Las Palmas (Canary Isl)



detecting cosmic gamma ray bursts

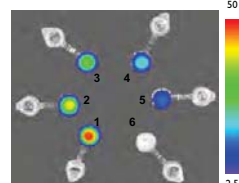
## Physics



## Medical CLI

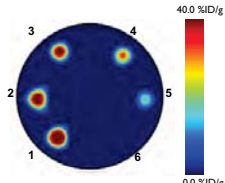
Radionuclides producing sufficiently energetic charged particles can be used to generate light and imaged with sufficiently sensitive optics.

Cerenkov luminescence imaging (CLI)



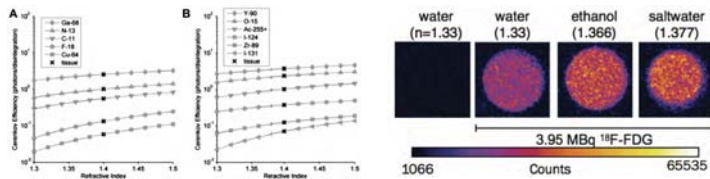
- |                                    |                                    |
|------------------------------------|------------------------------------|
| 1: 1.09 $\mu\text{Ci}/\mu\text{l}$ | 4: 0.55 $\mu\text{Ci}/\mu\text{l}$ |
| 2: 0.88 $\mu\text{Ci}/\mu\text{l}$ | 5: 0.36 $\mu\text{Ci}/\mu\text{l}$ |
| 3: 0.74 $\mu\text{Ci}/\mu\text{l}$ | 6: 0.00 $\mu\text{Ci}/\mu\text{l}$ |

PET imaging



## Refractive Index

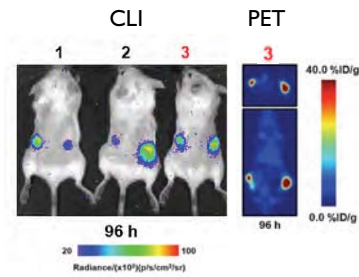
Increasing signal with increasing refractive index



Beattie B et al. (2012) PLOS 7(2)

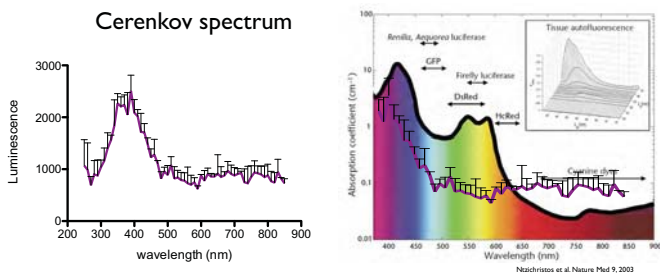
Thorek D et al. (2012) Am J Nucl Med Mol Imaging

## Faster Imaging

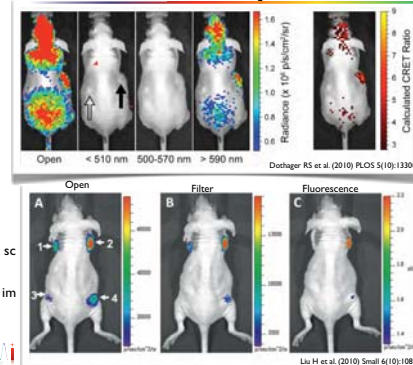


- More animals in less time
- 5 mice in 5 minutes vs. 1 mouse in 20 minutes
- optical imaging cheaper than PET
- allows for higher throughput
- high(er) throughput
- "cheap man's PET"

## Spectral Shift



## Multiplexed Imaging



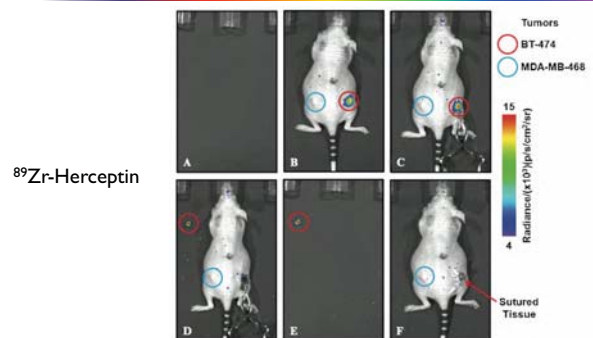
QTracker 705 QD + FDG  
Cerenkov radiation energy transfer (CRET)

## Clinical Applications

- Optical imaging of using *approved* radiotracers (FDG, antibodies etc.).
- Clinical application: endoscopy, intraoperative imaging = surface weighted
  - laparoscopic or open surgery
  - robotic surgery allows for better radiation shielding
- allows for true multi-modality imaging *and* pre- & post-operative PET mapping



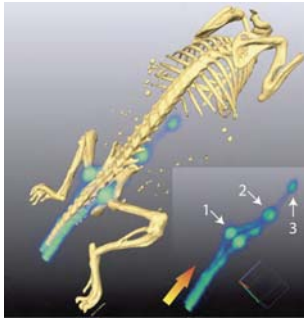
## Intraoperative Imaging



Holland J et al. (2011) Molecular Imaging 10(3):177

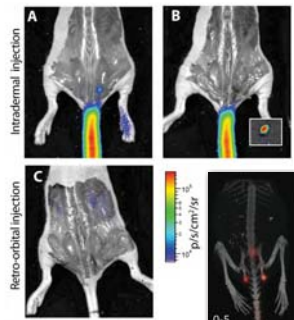
## Sentinel Lymph node imaging

### Positron Lymphography



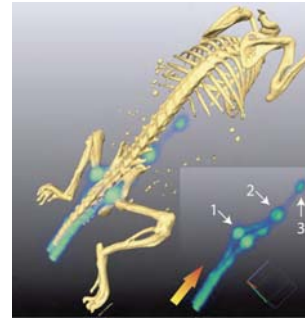
Thorek et al. (2012) JNM (in press); SS26, Thursday

### SLN detection



## Sentinel Lymph node imaging

### Positron Lymphography



Thorek et al. (2012) JNM (in press); SS26, Thursday



## Cerenkov Imaging

### Advantages (vs.)

- higher throughput (PET)
- cheaper (PET)
- better SNR for SCIFI (RFI)
- higher resolution (PET)
- approved tracers (RFI)

### Disadvantages (vs.)

- very low SI (PET, RFI)
- long imaging times (RFI)
- no real time imaging (RFI)
- demands no ambient light
- requires radioactivity

RFI: reflectance fluorescence imaging

## Challenges

- biggest challenge is low SI, need to exclude ambient light
- radioactive exposure of surgeons and patients
- especially challenging in an OR setting
- three possible solutions
  - laparoscopy (endoscopy)
  - darkening the OR
  - specialized filters & set up

## Grimm Lab



### Lab-Members

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Priyanka Shukla	Experimental Therapeutics Center
Dan Thorek	Gerstner Foundation
	MSKCC Society

<http://www.mskcc.org/research/lab/jan-grimm>