Fast & Accurate Biophotonic Simulation for Personalized Photodynamic Cancer Therapy Treatment Planning

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Partner Organizations: IBM and Theralase
PDT Cancer Treatment Simulation

Light (fluence) Distribution

Photosensitizer absorption

Reactive oxygen production

Tissue damage

Fiber light source

Isofluence contours

Fluence map on planar cut

(Lab mouse typically used for pre-clinical testing)
PDT Cancer Treatment Optimization

Image planning volume → Delineate organs → Define dose parameters → Propose plan → Simulate

~100-1000 iterations

10-60 min each on CPU
1000 times -> 1-6 weeks

Images courtesy of Robert Weersink
Princess Margaret Cancer Centre
Simulation Algorithm: Monte Carlo (MC)

- Trace photon packets as they scatter randomly and are absorbed

- Tetrahedral mesh for arbitrary shapes

- Compute-intensive
  - $10^7$-$10^9$ packets
  - $10^2$-$10^3$ steps each
  - 10-60s minutes with highly-optimized CPU code!
Goals: Research Team

1. Make PDT simulation both fast and accurate

2. Leverage fast simulator to enable automatic optimization of plan, and robustness evaluation with tissue variation

3. Develop full flow from MRI data through simulation to visualization

4. Increase PDT efficacy, and broaden applicability to more cancer indications
Goals: Partners

- IBM
  1. New application of IBM CAPI (agile) hardware in the medical space
  2. General utilities / APIs created by research team open-sourced → enable other agile computing users

- Theralase
  1. Provider of PDT photosensitizers and lasers: better PDT treatment planning → larger market
  2. Evaluate a treatment plan *in silico*: can tell if PDT plan will lead to a good result before treatment
  3. Automatic optimization: create a better and more robust treatment plan, quickly
Roles

■ Research team:
  – Betz: compute acceleration, software development
  – Lilge: medical physics modeling, PDT expertise
  – Together: develop complete software + hardware flow

■ IBM
  – Agile hardware, APIs, and simulation environments
  – Technical support and expertise on agile platform
  – Interaction with IBM researchers working on related medical simulation and imaging problems

■ Theralase
  – PDT and optical measurement expertise
  – Calibrate simulator against measured light / PDT results
Achievements to Date

- World’s fastest software simulator for general Monte Carlo simulation of light

- Agile hardware implementation in progress
  - Single compute pipeline functions in simulation
    - But still debugging in actual hardware
  - 4x performance of high-end, four-core CPU
  - Expect ~16x performance and 60x power-efficiency for scaled-up full system

- Prototype components of most of MRI image → simulation → visualization flow
OCE and SOSCIP Role & Support

- **OCE** very helpful through entire application process
  - Suggested the VIA program
  - Walked us through the rules and application procedure
  - Answering questions and overcoming roadblocks

- **SOSCIP & IBM**
  - Hardware & great technical support
  - Support for funding applications, and direct funding
  - Linkages and introductions to other researchers

- **OCE and NSERC Funding**
  - Strong matching → expand goals & team
  - Strong matching → encourages industrial support
    - Broadens team expertise
  - Key to realizing our larger vision!