

Fotoacústica: imagens da interação de som e luz com o corpo humano

Theo Zeferino Pavan

Professor Doutor do Departamento de Física da Faculdade de Filosofia, Ciências e Letras de Ribeirão Preto

06 de setembro de 2018

theozp@usp.br

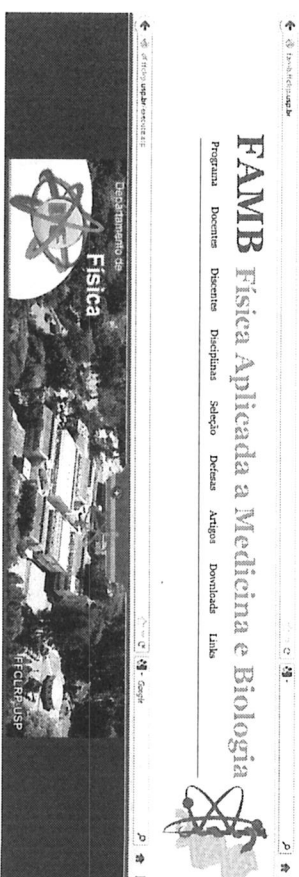
GIIMUS



Contato: theozp@usp.br
www.giimus.usp.br

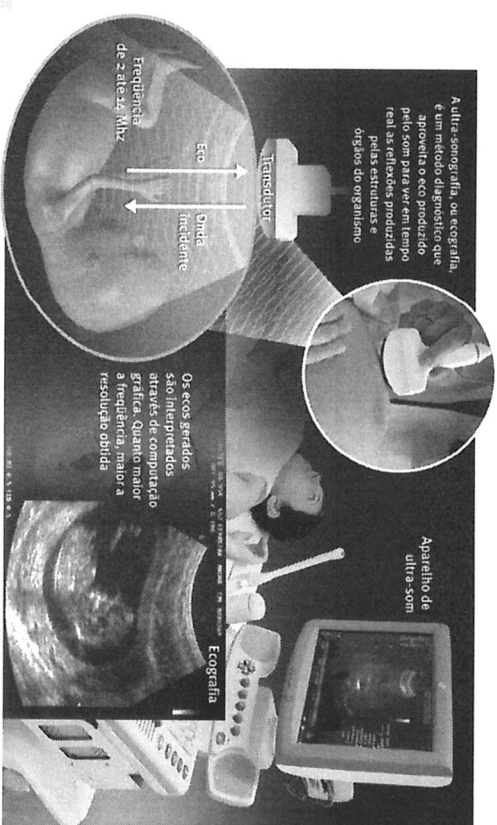
FAMB Física Aplicada a Medicina e Biologia

Programa Docentes Discentes Disciplinas Seleção Bolsas Artigos Downloads Links



MINISTÉRIO DA CIÊNCIA E TECNOLOGIA

Ultrassom

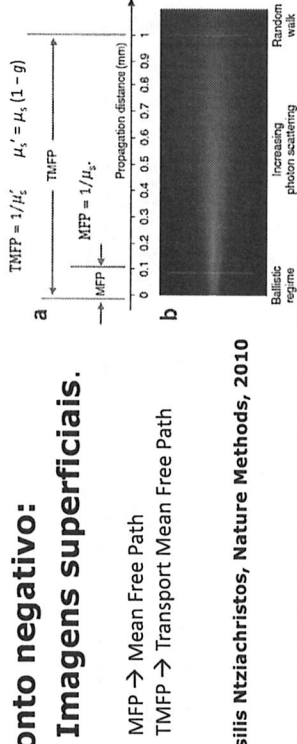


→ Excelente resolução espacial.

→ Imagens funcionais e moleculares.

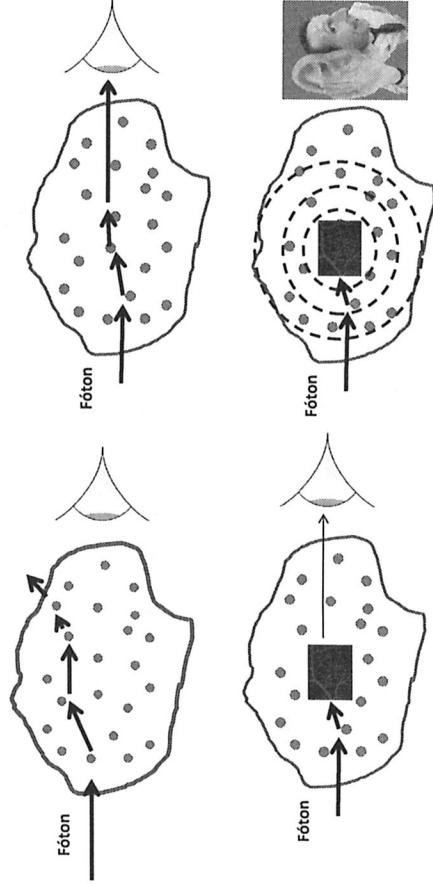
→ Ponto negativo:

→ Imagens superficiais.



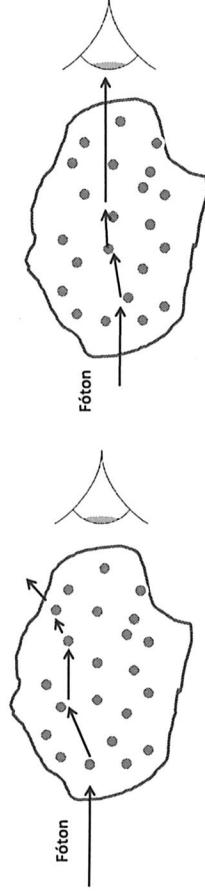
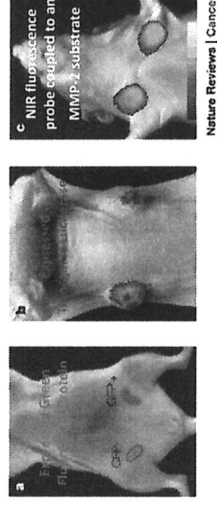
Vasilis Ntziachristos, Nature Methods, 2010

Motivação: Imagem Fotoacústica



Nature Reviews Cancer 2, 11-18 (January 2002) | doi:10.1038/nrc701
<http://www.nature.com/nrc/journal/v2/n1/full/nrc701.html>

Scaling down imaging: molecular mapping of cancer in mice



Motivação

Ultrassom :

- Excelente resolução espacial, excelente imagens anatômicas.
- Disponível na clínica médica.
- Limitada na visualização de eventos fisiológicos, como concentração de hemoglobina oxigenada no sangue. ←

Imagens ópticas:

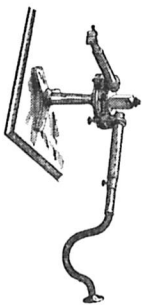
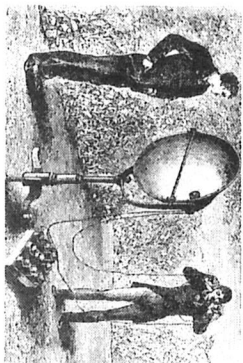
- Devido a fenômenos como absorção, é uma excelente ferramenta na visualização funcional de eventos fisiológicos (concentração de hemoglobina oxigenada, lipídio, etc).
- Fenômenos como difração e espalhamento limitam a profundidade de obtenção de imagens. ←

Imagem fotoacústica:

Gerar imagens baseadas na absorção da luz a partir de detecção de onda ultrassônicas.

Efeito fotoacústico

Fotofone



Inventado por Alexander
Graham Bell em 1880

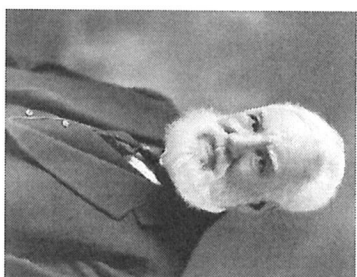
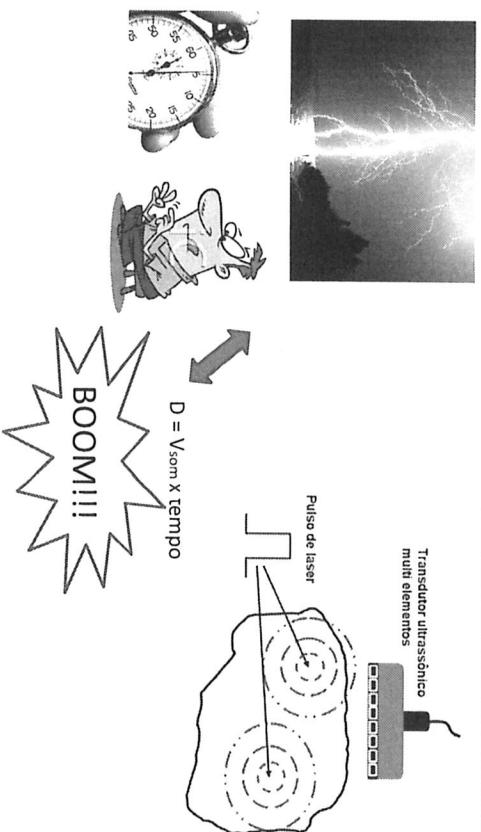
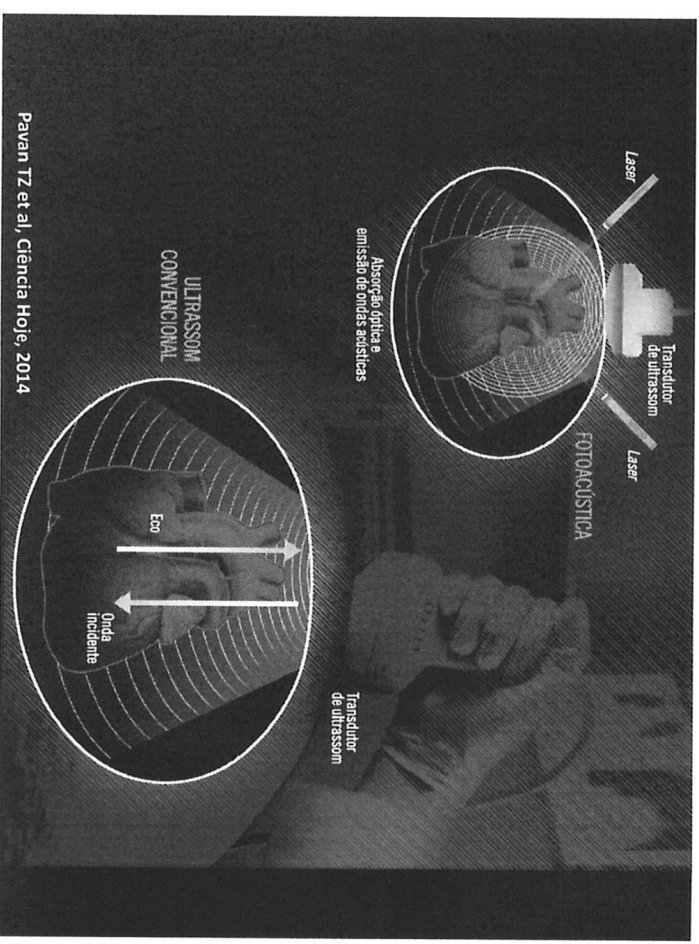
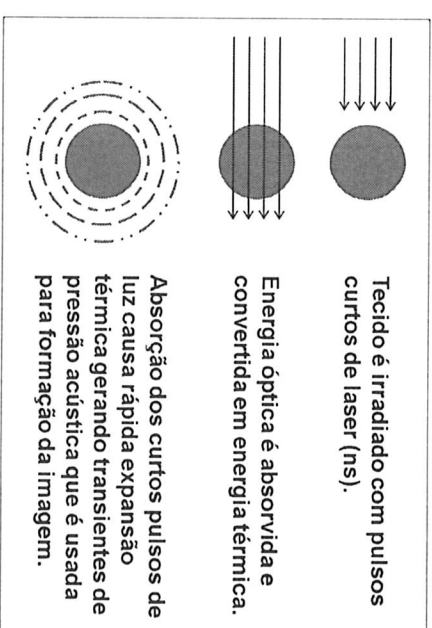


Imagem fotoacústica

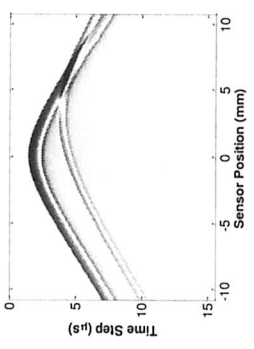
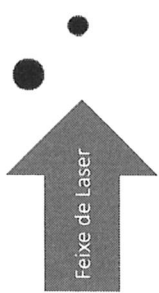


Expansão termelástica

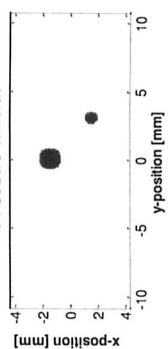


Reconstrução da imagem usando array linear

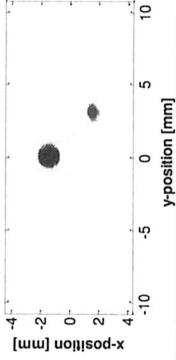
Array de sensores



Distribuição dos absorvedores de luz



Reconstruída



Treeby B.E., Cox B.T., JBO, 2010 www.k-wave.org

Nosso Laboratório de Fotoacústica

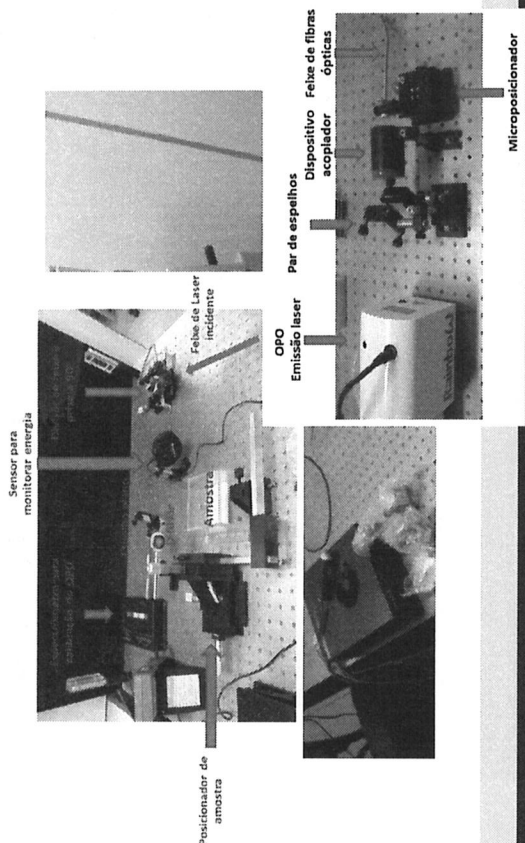
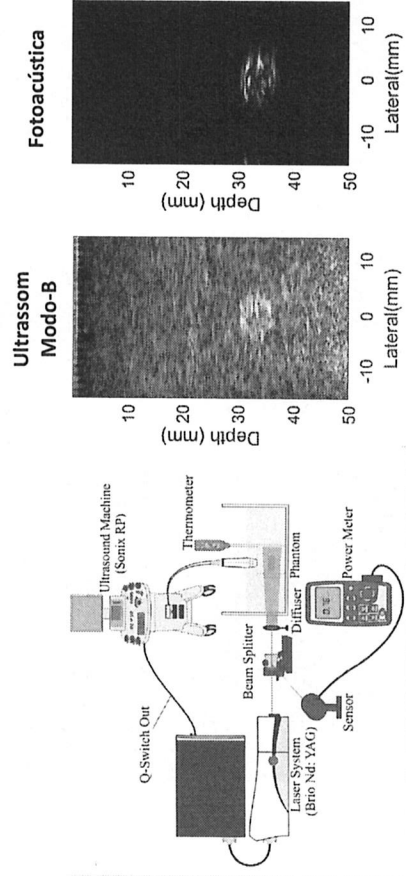
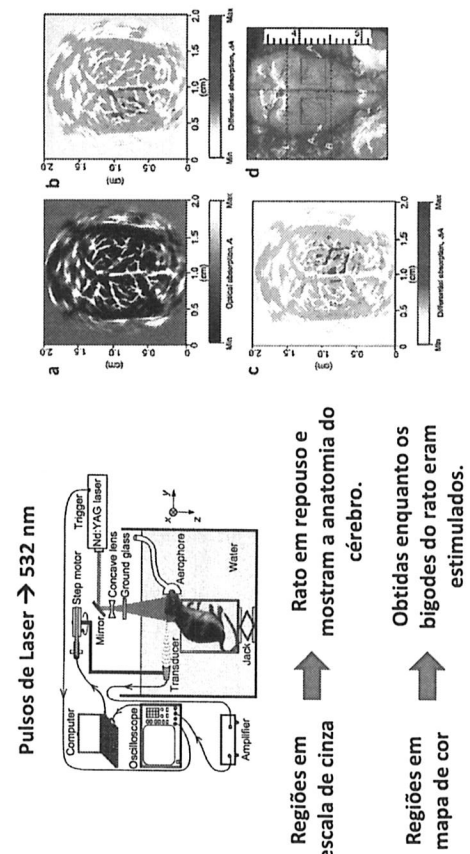


Imagem Phantom



Imagens funcionais do cérebro



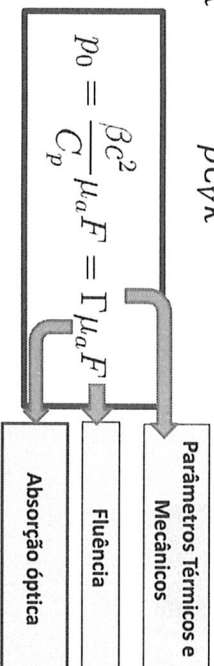
Wang, et al., Nature Biotechnology, 2003

Initial Photoacoustic Pressure:

$$\frac{dV}{V} = -\kappa dp(r) + \beta dT(r) \quad t_0 < \frac{l}{c} < \frac{l^2}{4D_T}$$

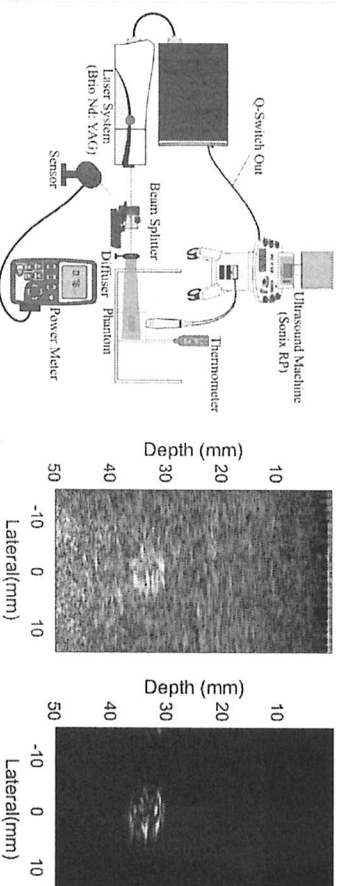
$$\kappa = \frac{C_p}{\rho c^2 C_V}$$

$$p_0(r) = \frac{\beta T(r)}{\kappa} = \frac{\beta \mu_a(r) F(r)}{\rho C_V \kappa}$$



Welch, A. J., & van Gemert, M. J. C. (Eds.). (2011). *Optical-Thermal Response of Laser-Irradiated Tissue*. Optical-Thermal Response of Laser-Irradiated Tissue (2nd Edition). NY: Springer-Verlag. <https://doi.org/10.1007/978-90-481-8831-4>

Imagem Phantom



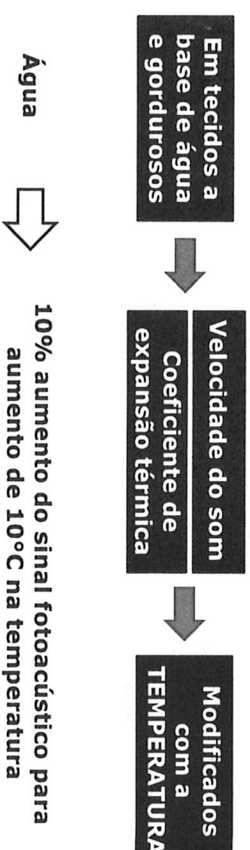
Uliana et al., RBE, 2018

Sinal fotoacústico e temperatura

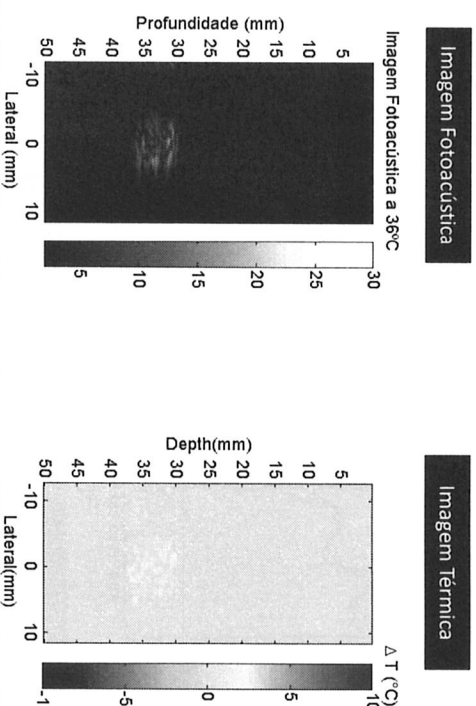
$$p_0 = \frac{\beta c^2}{C_p} \mu_a F = \Gamma \mu_a F$$

Parâmetro de Gruenesein

Depende da temperatura do meio

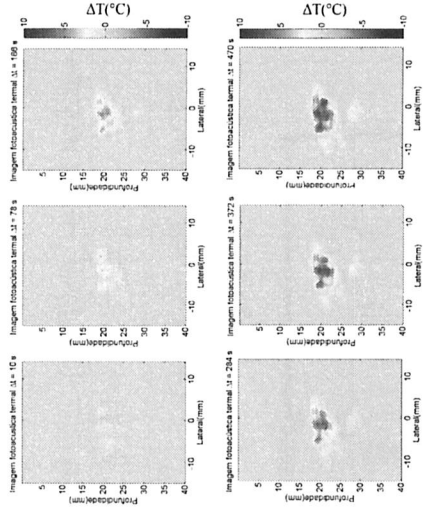
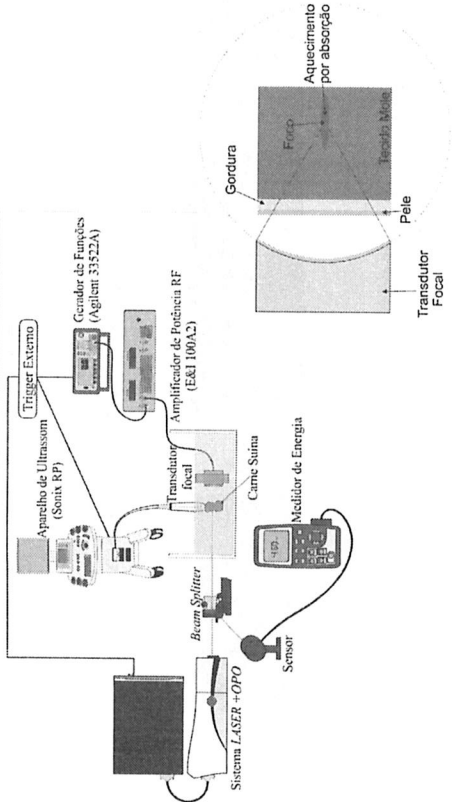


Monitorar Temperatura

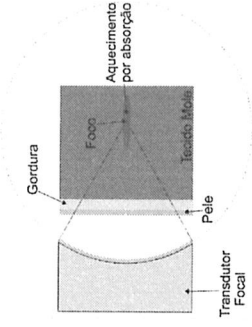


Uliana et al., RBE, 2018

Monitorar temperatura HIFU

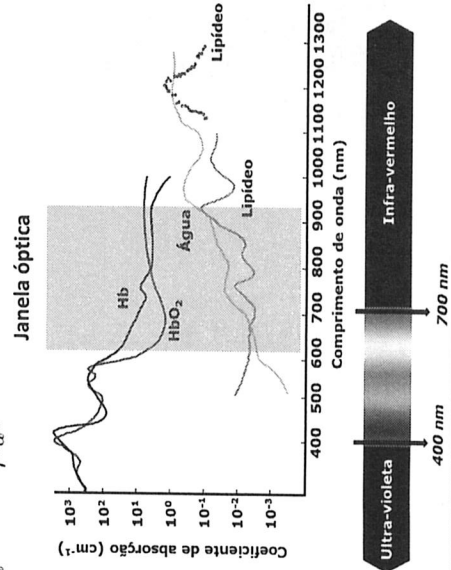


Monitorar temperatura HIFU



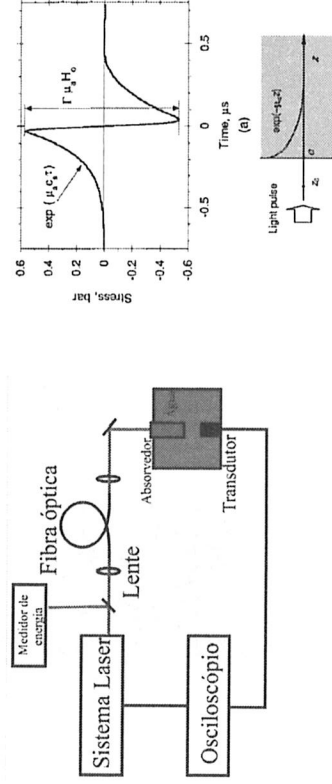
Equação fotoacústica Dependência com λ

$$p_0 = \frac{\beta c^2}{C_p} \mu_a F = \Gamma \mu_a F$$



Equação fotoacústica Dependência com λ

$$p_0 = \Gamma \mu_a F_0 e^{-z(\mu_{eff})}$$

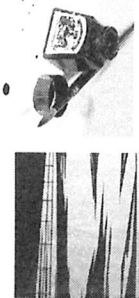


Agradecimentos → João H. Uliana e Vivian Tetzner

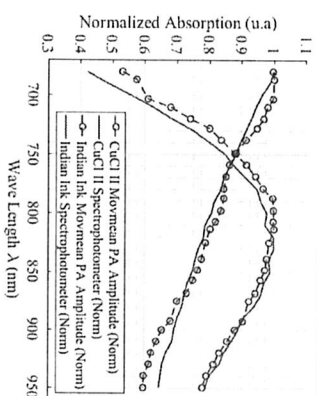
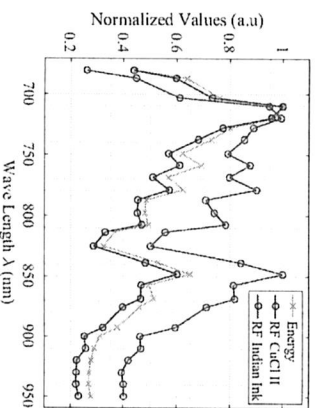
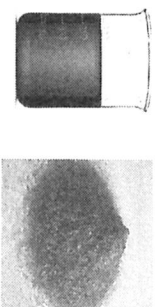
FIG. 1. Diagrama d' initial pressure distribution.

Equação fotoacústica Dependência com λ

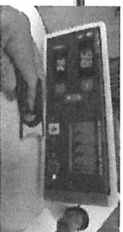
India Ink



CuCl_2



Saturação de oxigênio



- Oxygen saturation is the fraction of oxygen-saturated hemoglobin relative to total hemoglobin.
- Normal blood oxygen levels in humans are considered 95–100 percent. If the level is below 90 percent, it is considered low resulting in hypoxemia.

Fonte: Wikipedia

$$\mu_a(\lambda_i) = \epsilon_{Hb}(\lambda_i)[Hb] + \epsilon_{HbO_2}(\lambda_i)[HbO_2]$$

$$SO_2 = \frac{[HbO_2]}{[HbO_2] + [Hb]}$$

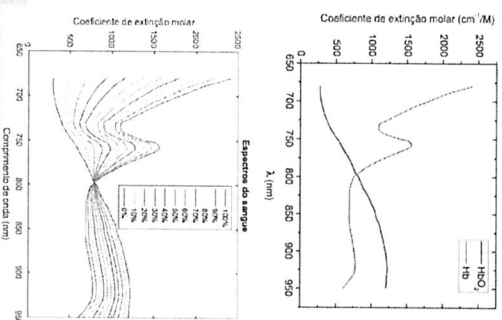
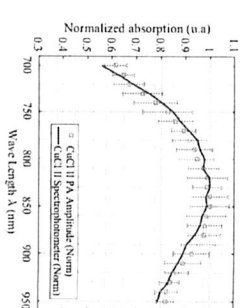
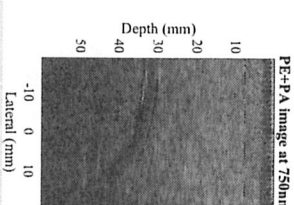


Imagem Espectroscópica

- Phantom de SEBS com TiO_2
- Mimetizador de vaso sanguíneo com CuCl_2

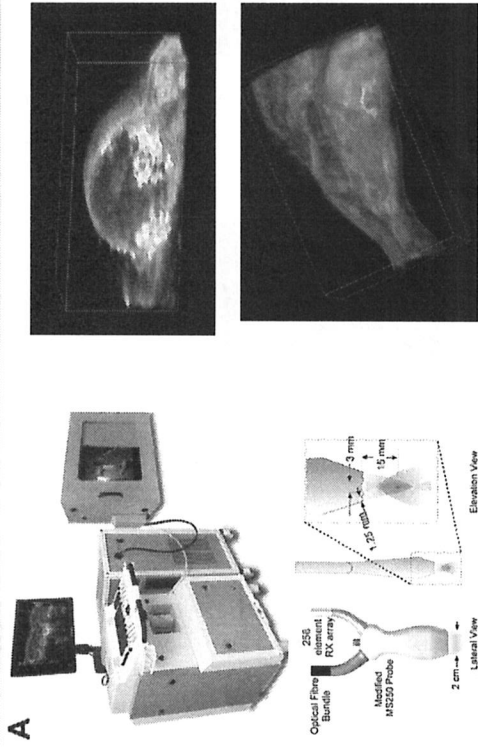


Cabrelli et al. PMB, 2017
Cabrelli et al. UMB, 2017

Medida de saturação de oxigênio por imagens fotoacústicas - Motivação

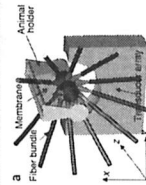
- Informações funcionais: equilíbrio entre fornecimento e consumo de oxigênio nos tecidos
- Diagnóstico - Alteração no equilíbrio entre fornecimento e consumo de oxigênio nos tecidos: doenças arteriais, câncer, etc...
- Nível de oxigenação nos tumores afeta a radio-sensibilidade do tecido, influenciando na efetividade de tratamentos de radioterapia.

Equipamentos comerciais – pequenos animais

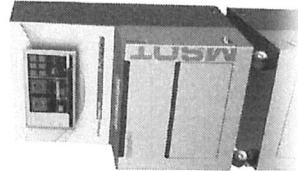


<https://www.visualsonics.com/application/precinical/biomarker-molecular-imaging>

Equipamentos comerciais – pequenos animais



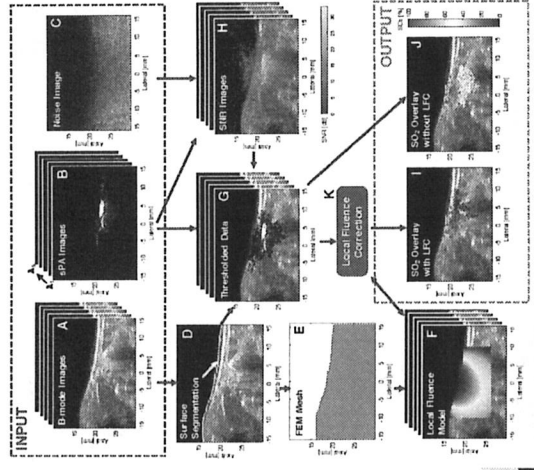
Deán-Bem et al., Chem. Soc. Rev., 2017



<https://www.ithera-medical.com>

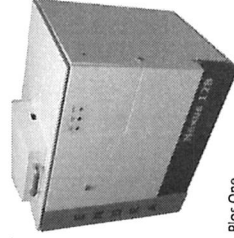


Correção Fluência e SNR

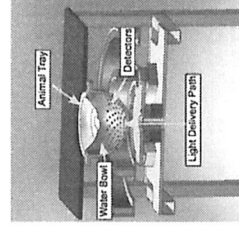


Mohamed A. Naser,
Diego R. T. Sampaio et.
al., IEEE-TMI, Accepted

Equipamentos comerciais – pequenos animais

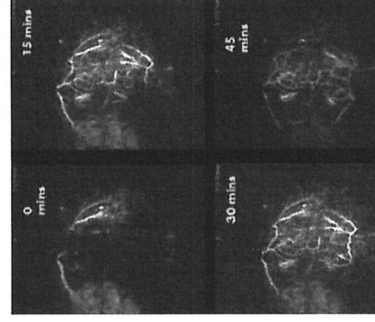


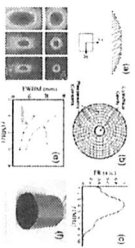
Bohndiek et al. Plos One,
2013



This example looks at the gold nanoparticle uptake
of an orthotopic mouse model of glioblastoma.

<http://www.ayt.com.au/precinical-photoacoustic-scanner-nexus-128/#143890865096-2-5>

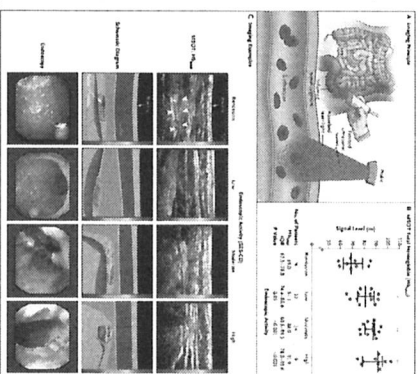
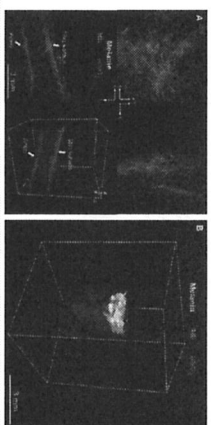




Viral wart

Basal cell carcinoma

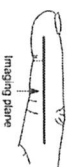
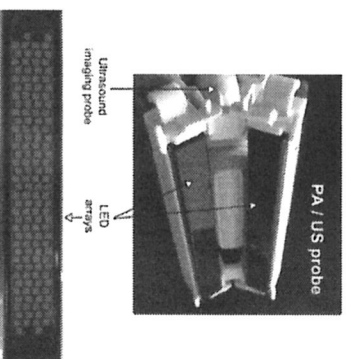
Inflammatory bowel disease
Crohn's disease



Attia et al., Photoacoustics, 2017

Kniering F. et al. N Engl J Med. 2017

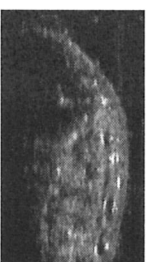
Equipamentos comerciais



PA + US



imaging probe



Xia et al., Sensors, 2018

Tomógrafo de mama

TomoWave (www.tomowave.com)

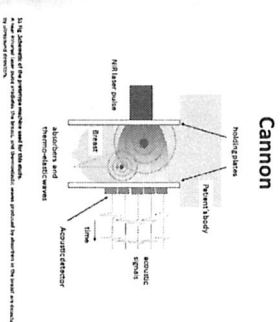
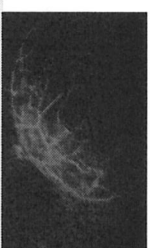
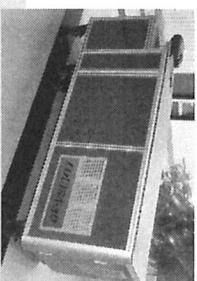
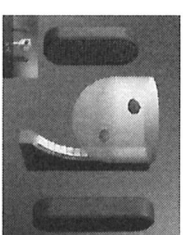
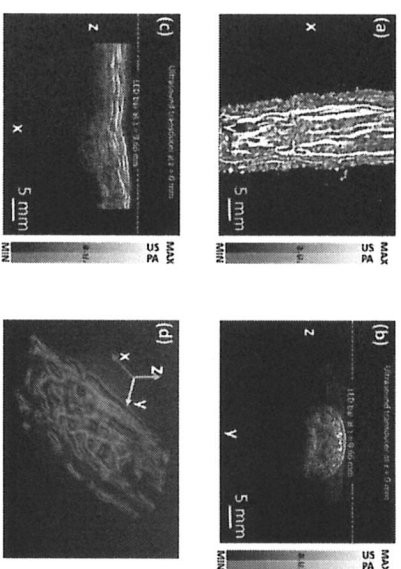


Imagem 3D

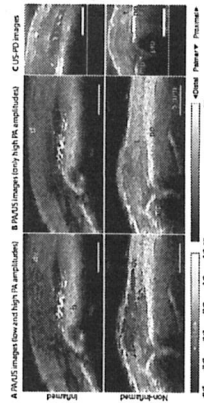
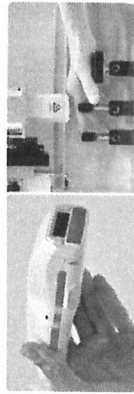


Zhu et al. Scientific Reports, 2018

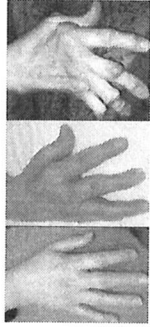


Aplicação Clínica – Artrite reumatoide

- Doença autoimune.
- Qualidade de vida piorada.

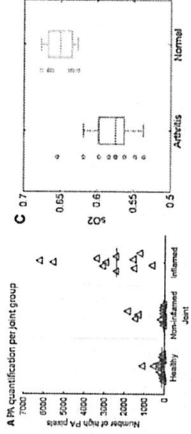


van den Berg et al., Photoacoustics, 2017



https://pt.wikipedia.org/wiki/Artrite_reumatoide

Jo et al. Scientific Reports, 2017



Contato: theo zp@usp.br

Grupo de Inovação em Instrumentação Médica e Ultrassom
www.giimus.usp.br



FAMB Física Aplicada a Medicina e Biologia

Programa Docentes Disciplinas Seleção Defesas Artigos Download Links

