

# **Surface-Enhanced Raman Spectroscopy (SERS) for Intraoperative Brain Tumor Imaging and Photothermal Therapy**

Hamed Arami

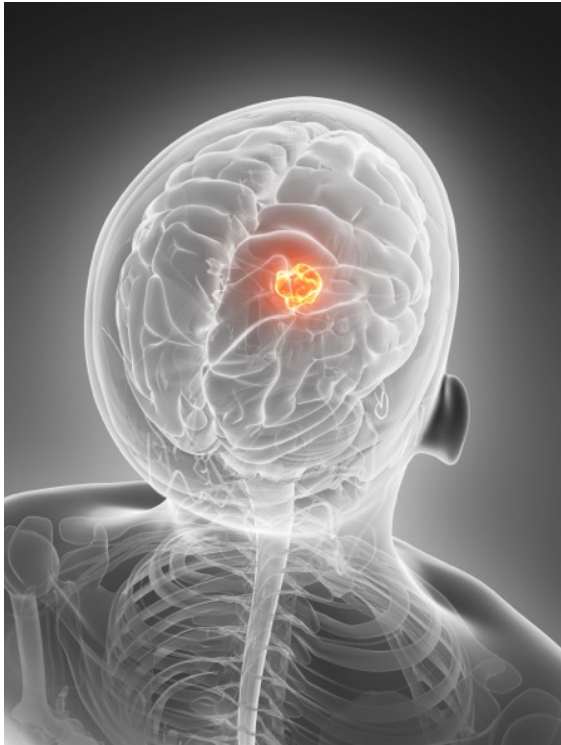
**SCIT seminar, October 05, 2017**

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**Stanford University  
Department of Radiology  
School of Medicine**



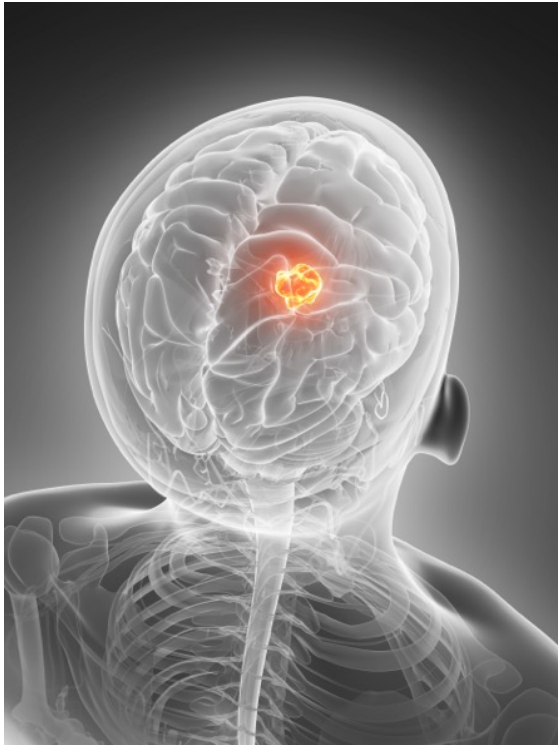
# Background: Intraoperative Detection of Brain Tumors



- Intraoperatively it is difficult to distinguish the exact margin between brain tumors and the adjacent normal brain tissue.
- Residual cancer cells result in tumor recurrence.
- Resection that includes normal brain tissue can result in neurological deficits.
- Developing intraoperative methods to better delineate brain tumor margins



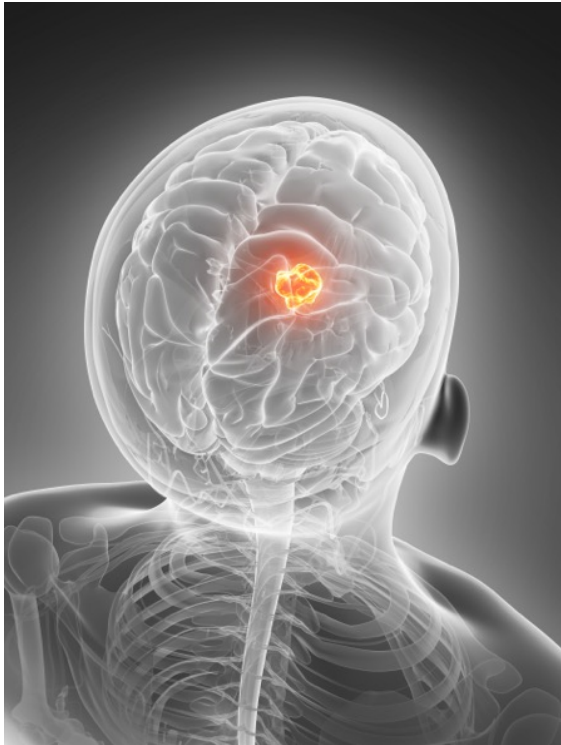
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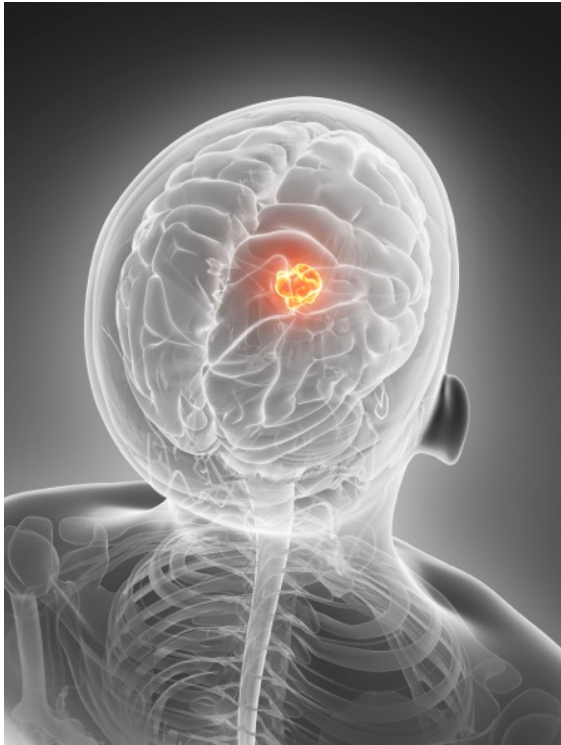
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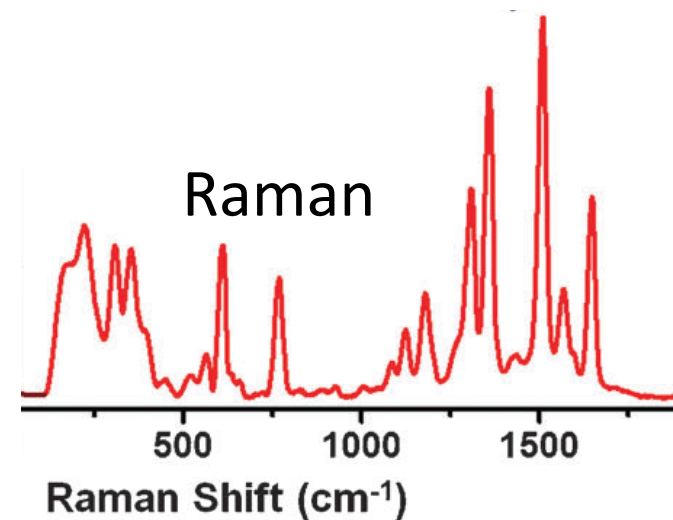
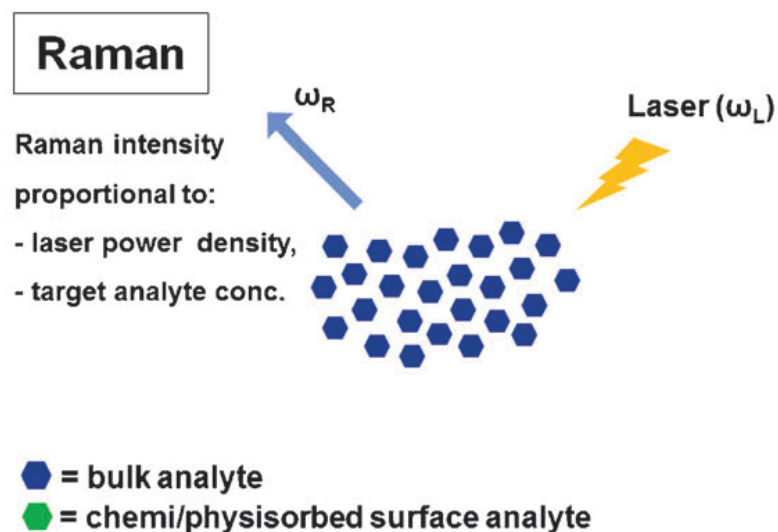
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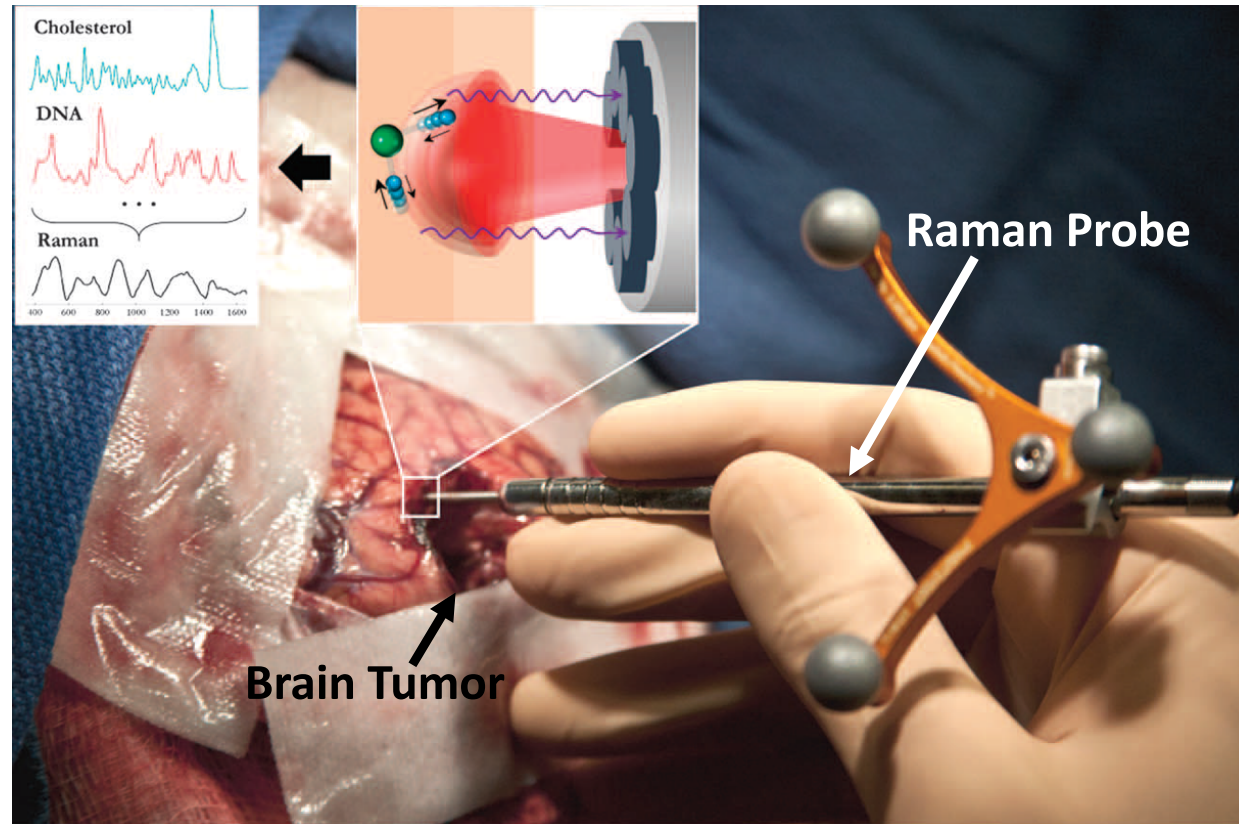
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# Background: Surface Enhanced Raman Spectroscopy (SERS)



# Background: Intraoperative Raman Spectroscopy in Humans

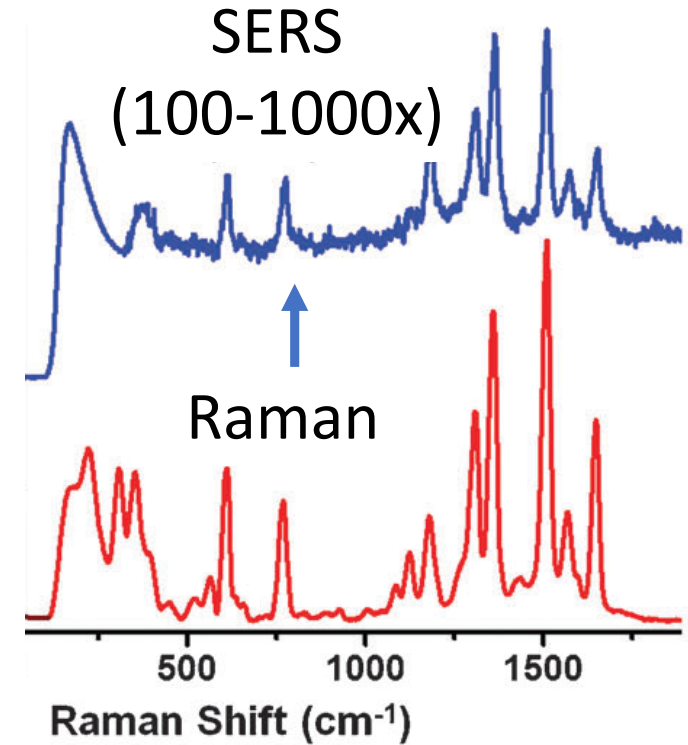
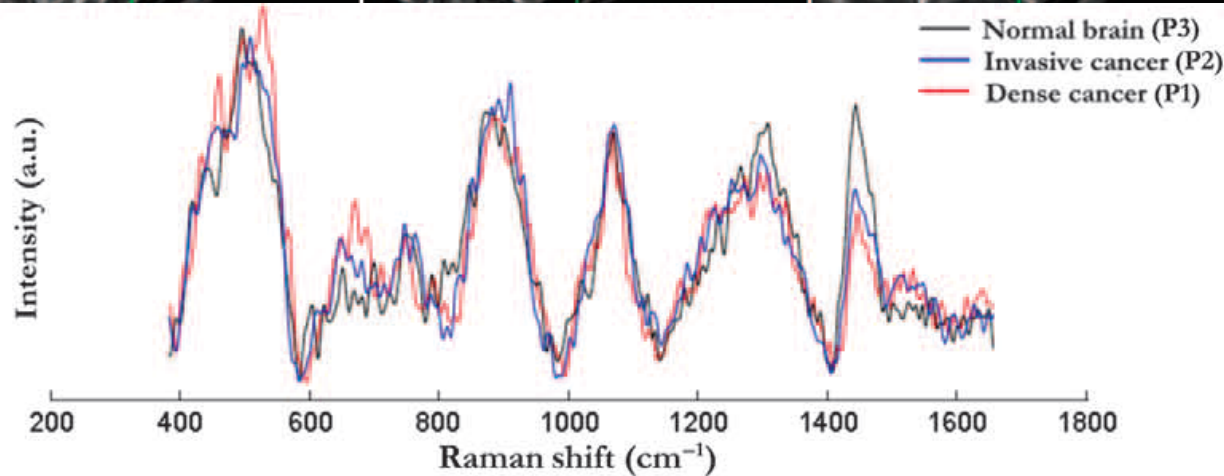
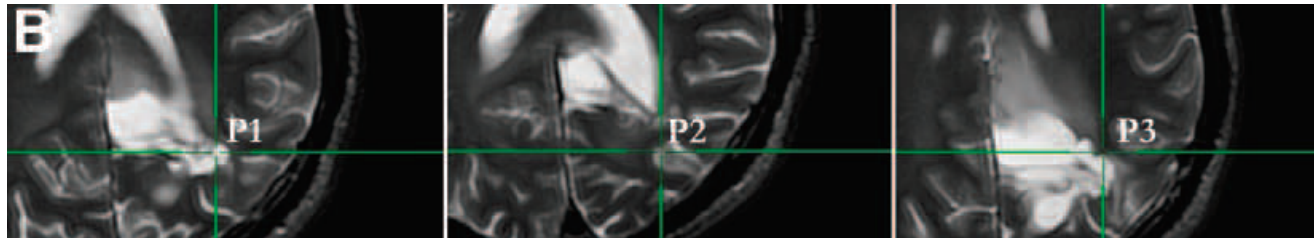


M. Jermyn et al. Science Translational Medicine, 2015.

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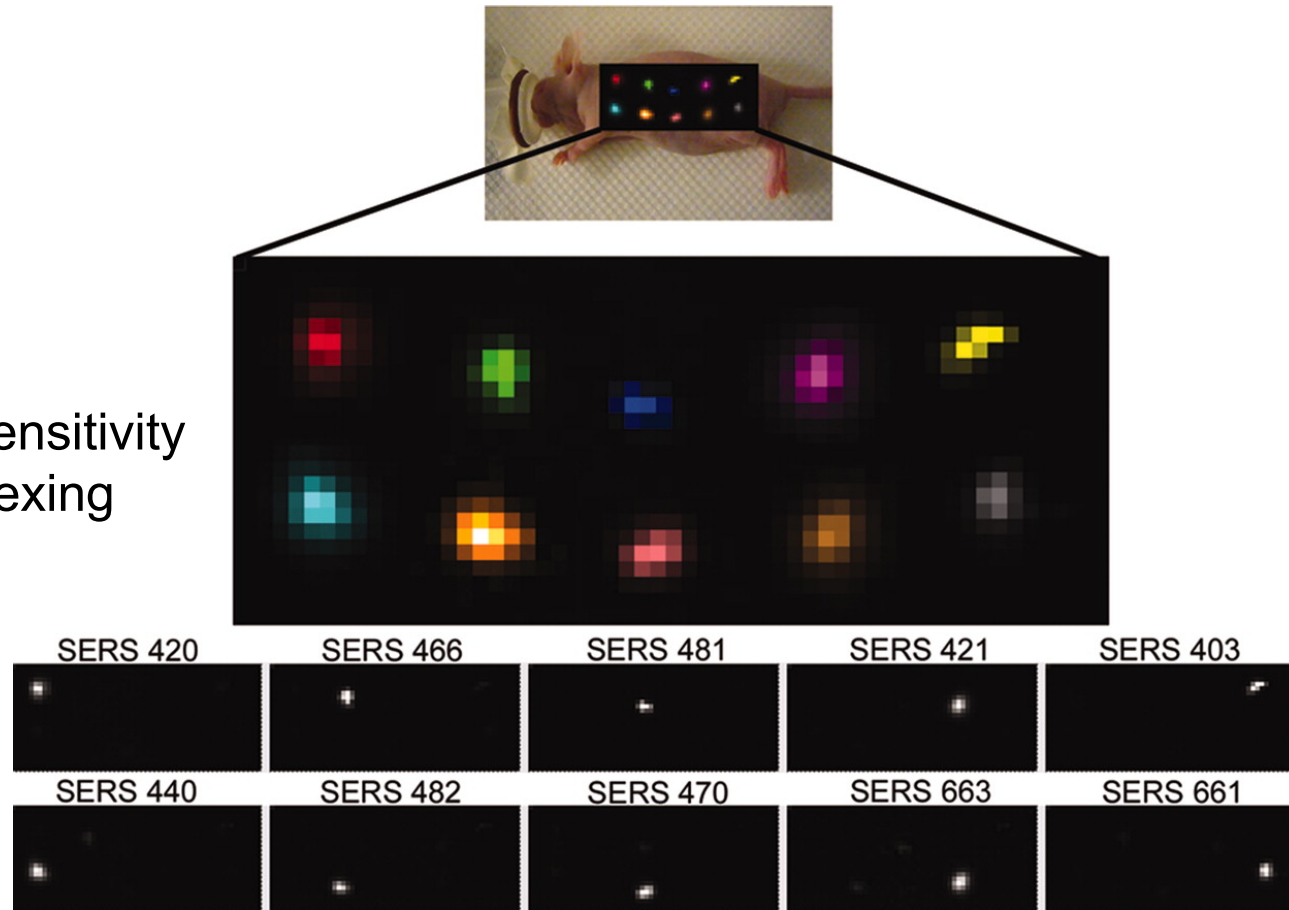
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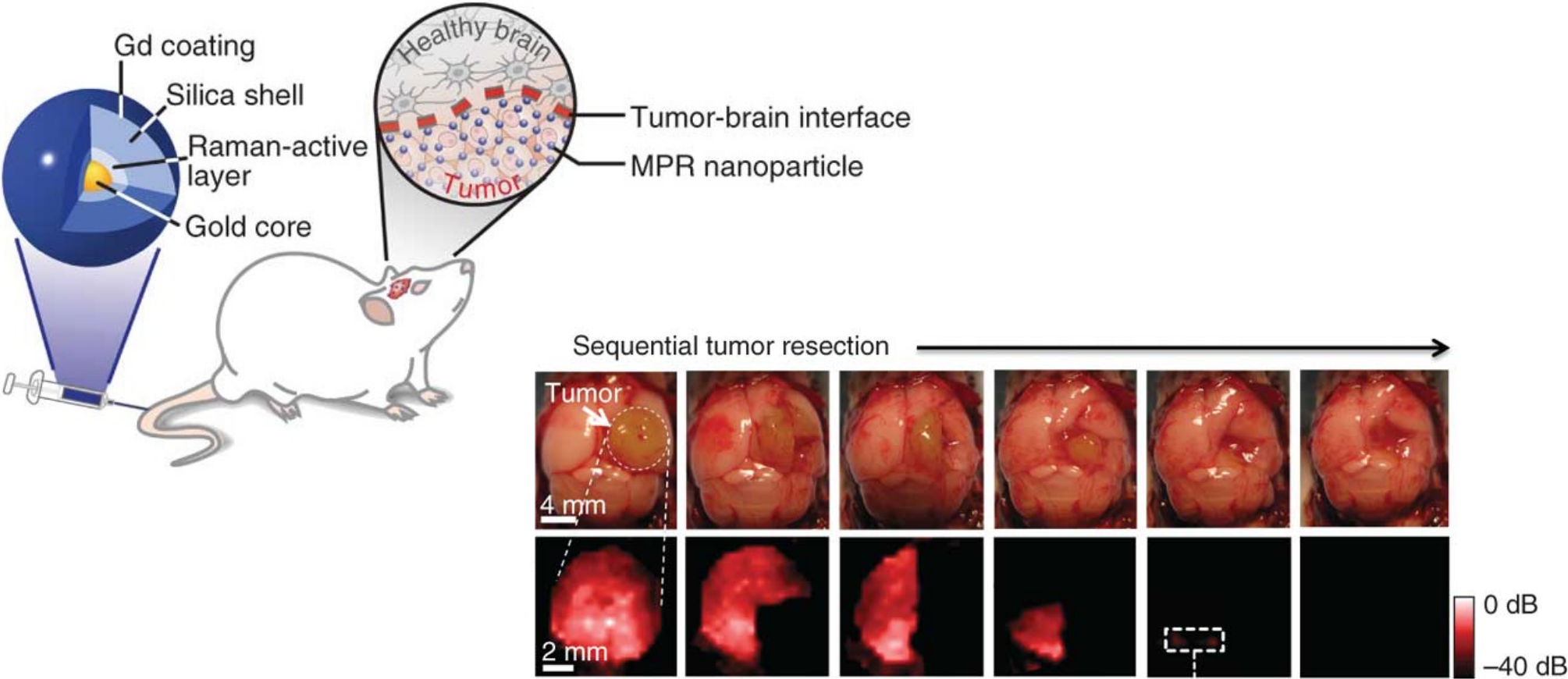


# Background: In Vivo Evaluation of Multiplexing Different NPs

- High sensitivity
- Multiplexing

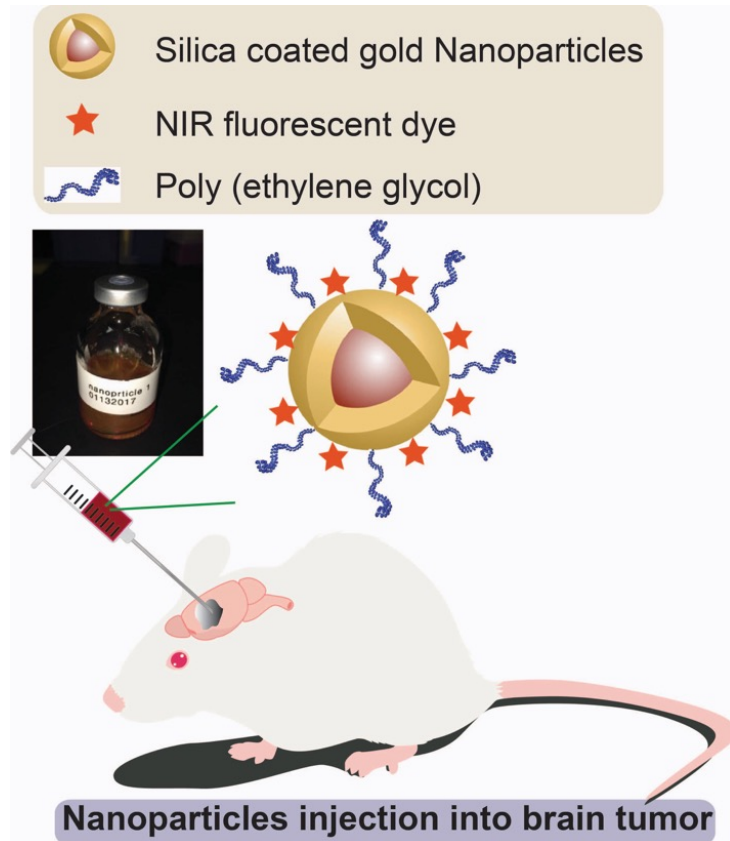


# Background: Intraoperative Surface Enhanced Raman Spectroscopy

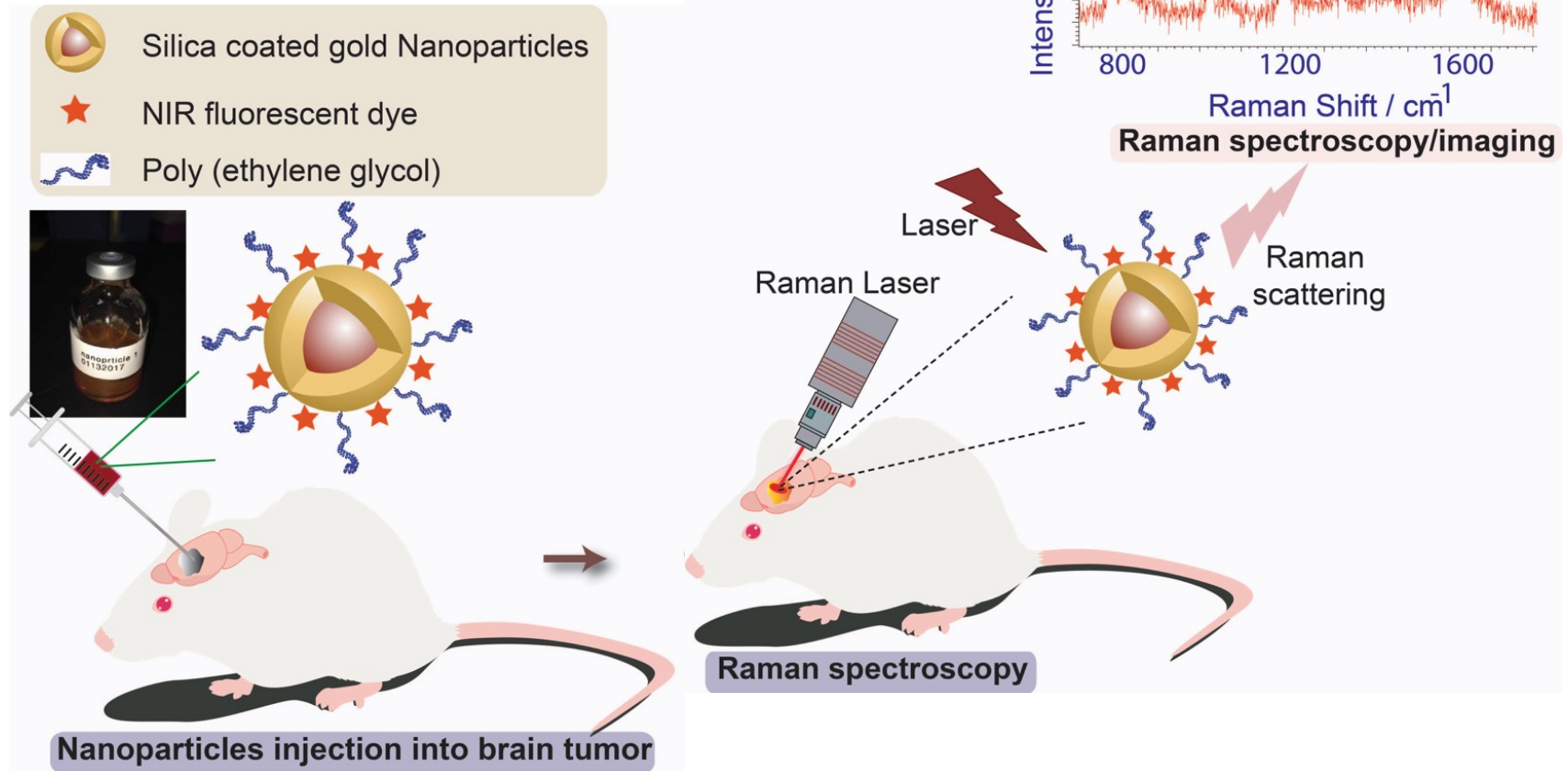


M. Kircher et al. Nature Medicine, 2012.

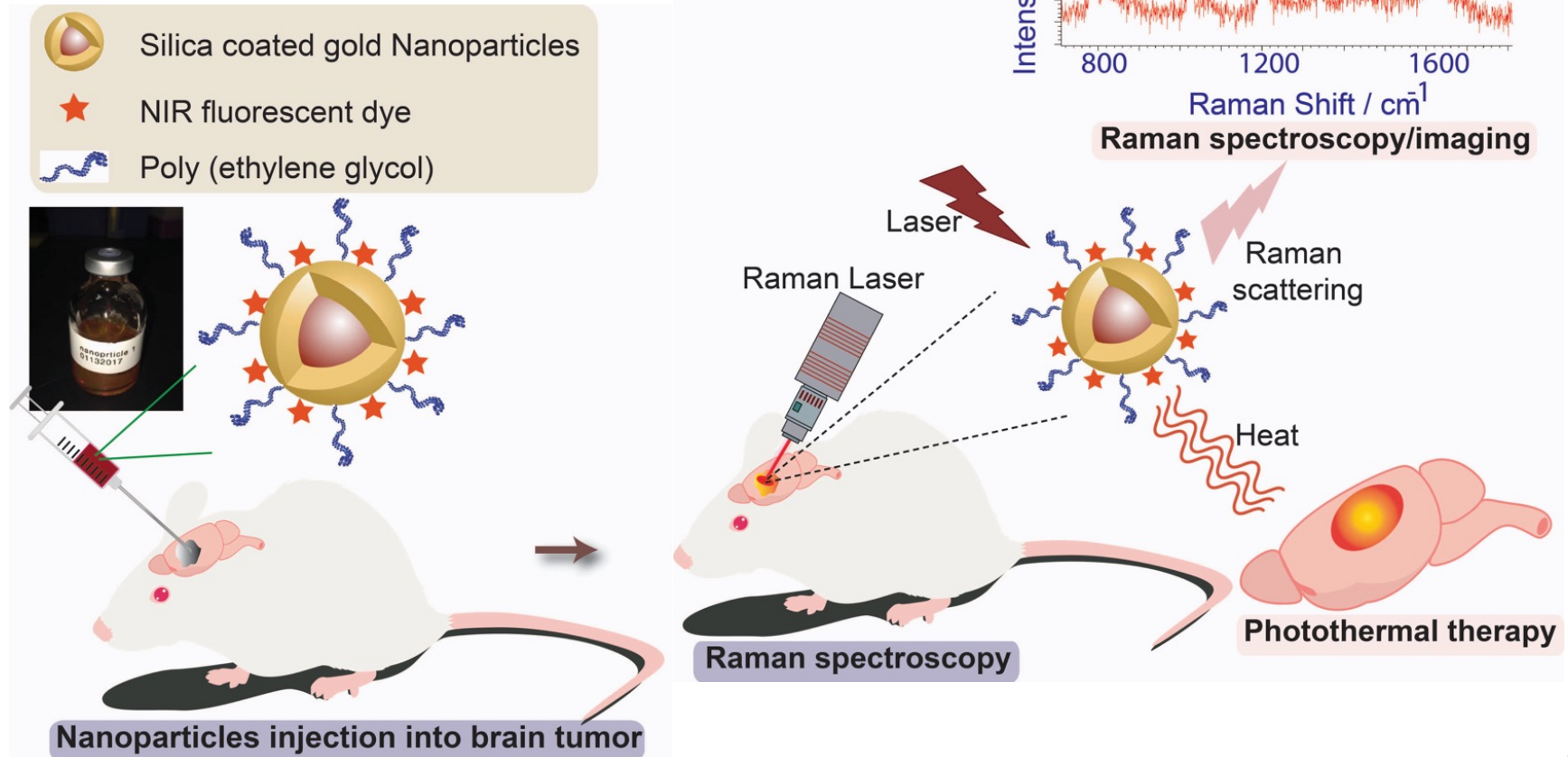
# Aims, Significance & Study Design



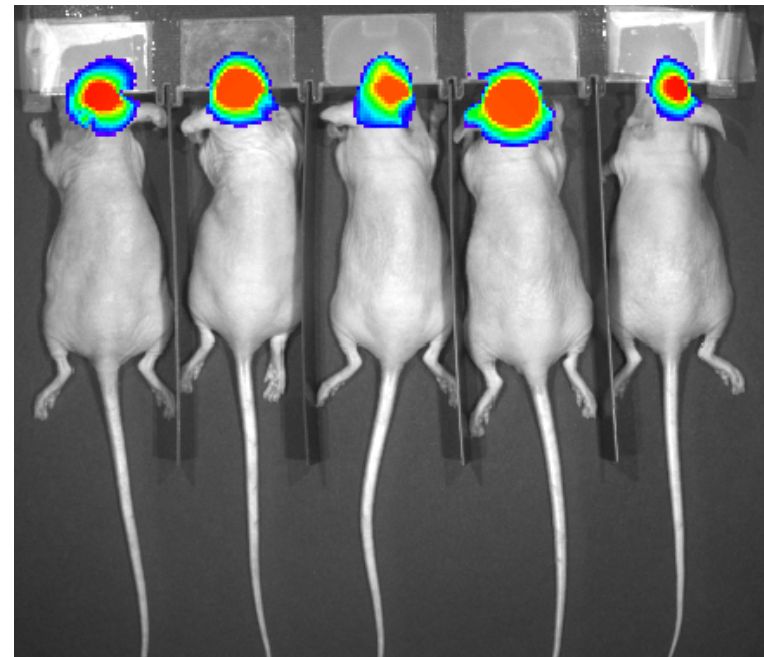
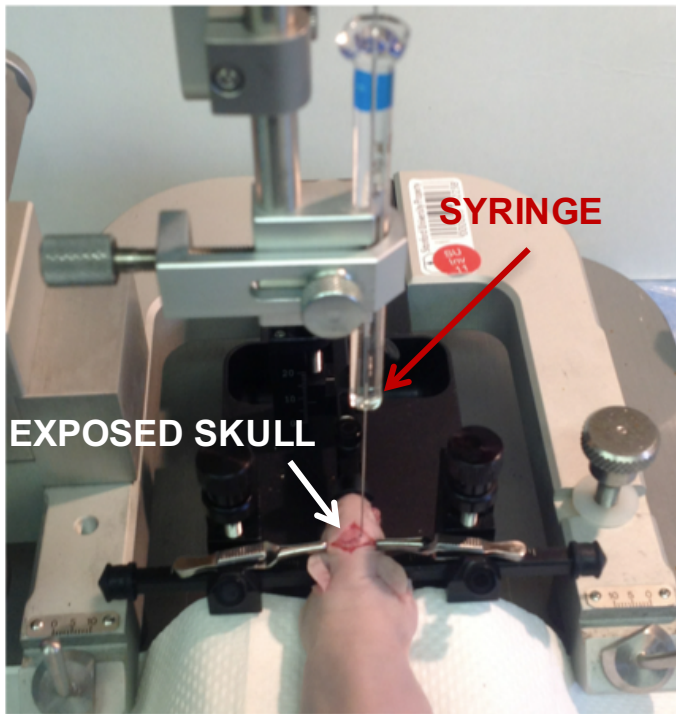
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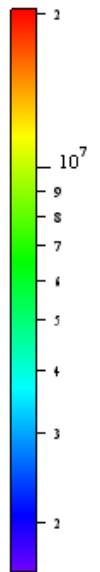
# Aims, Significance & Study Design



# Methods: Tumor Implantation and Bioluminescent Imaging (U87 Brain Tumor Cells)



Luminescence

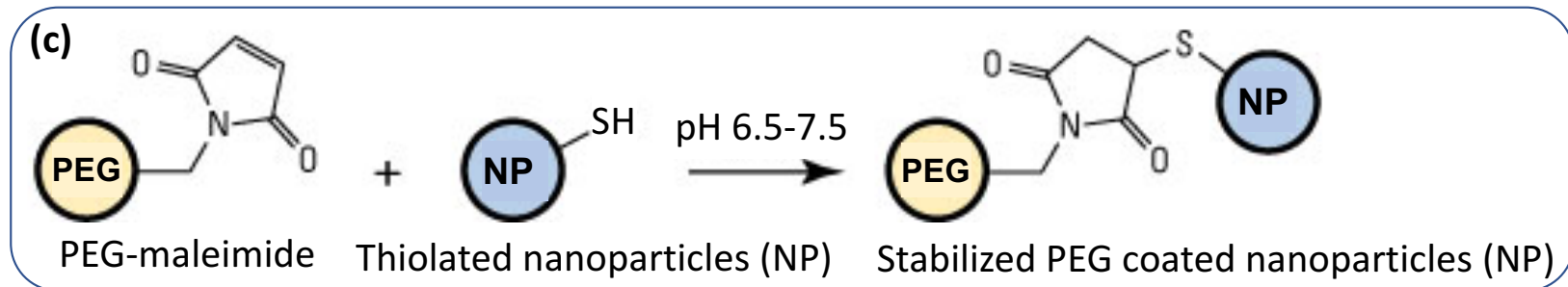
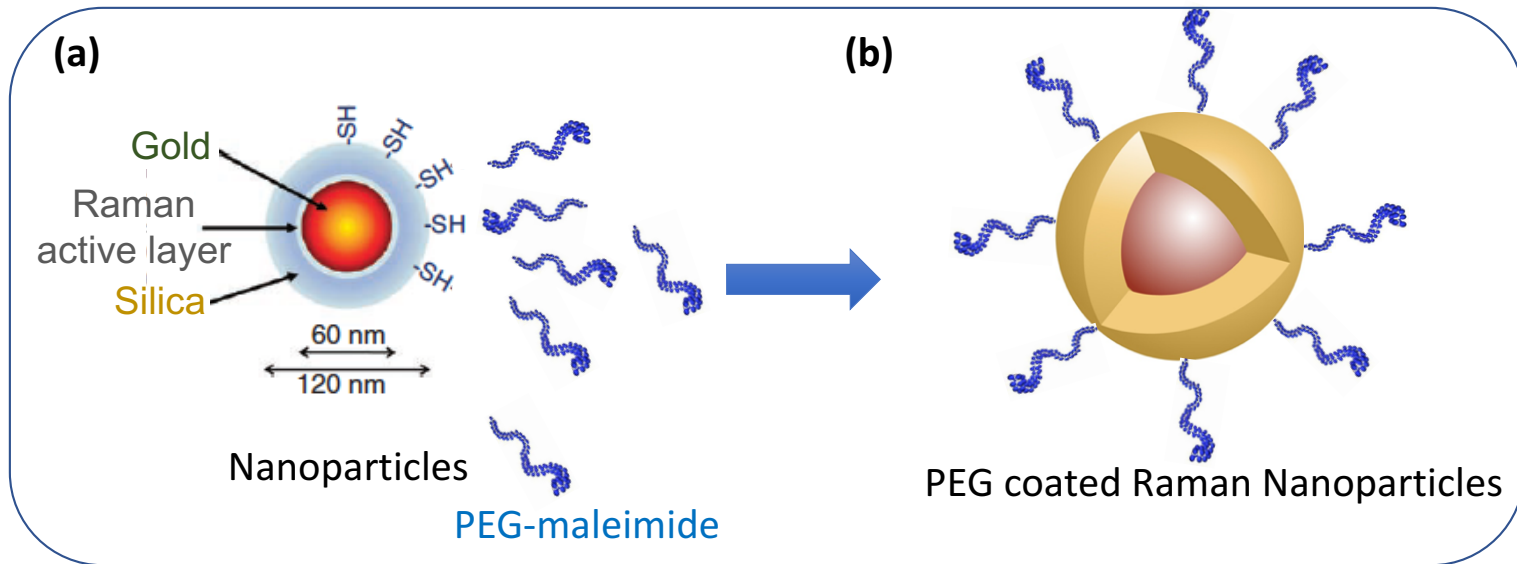


Radiance  
(p/sec/cm<sup>2</sup>/sr)

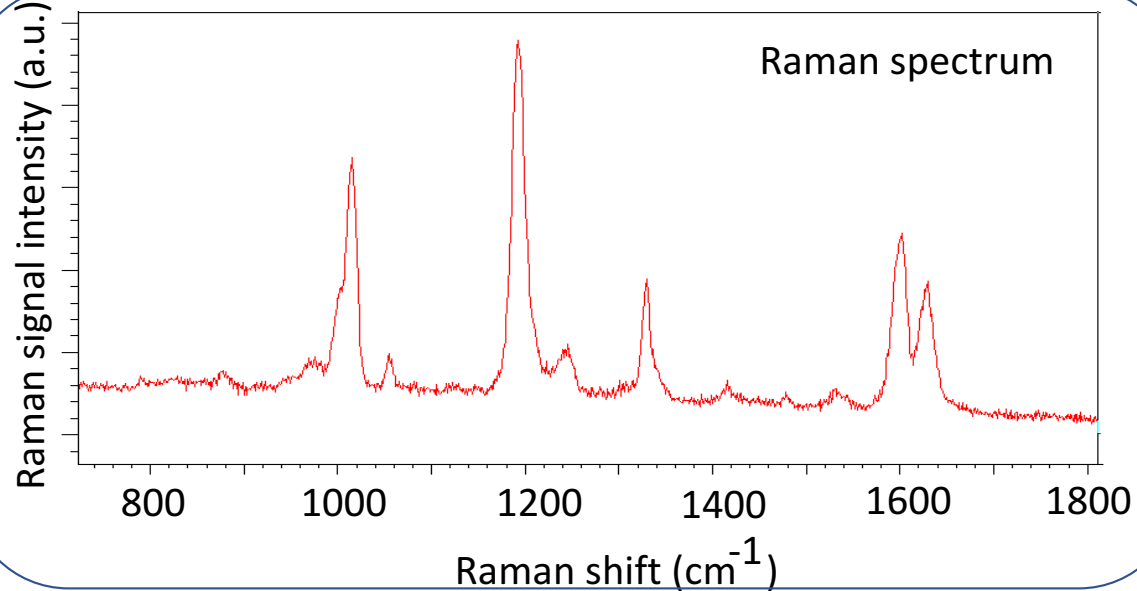
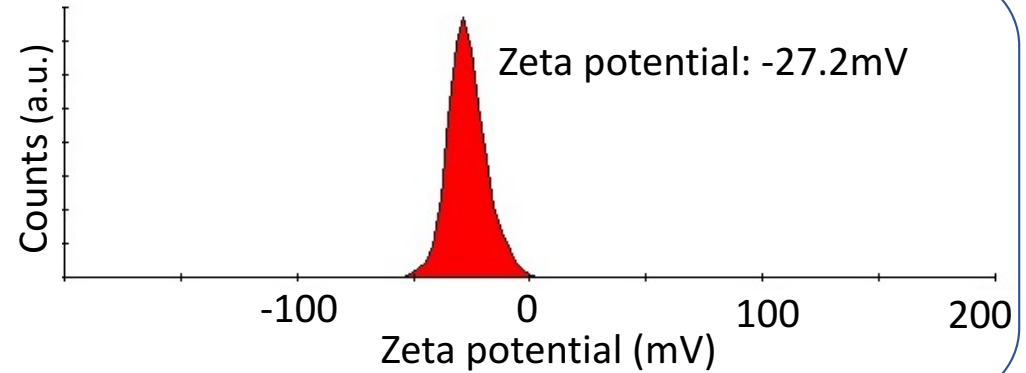
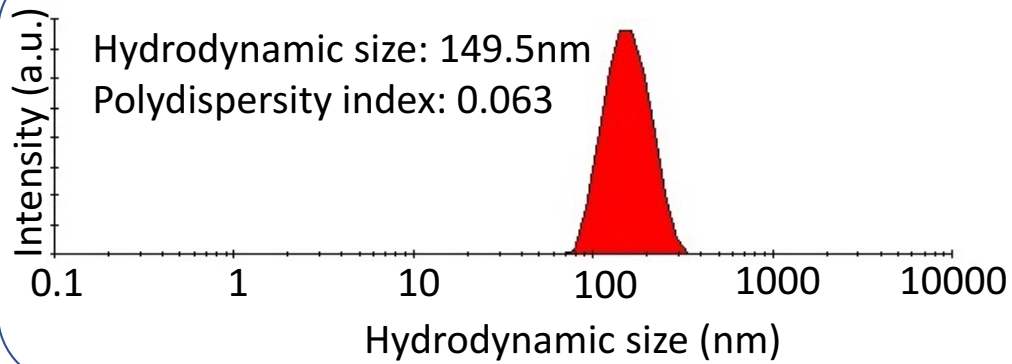
Color Scale  
Min = 1.60e6  
Max = 2.04e7



# Methods: Preparation of the Nanoparticles



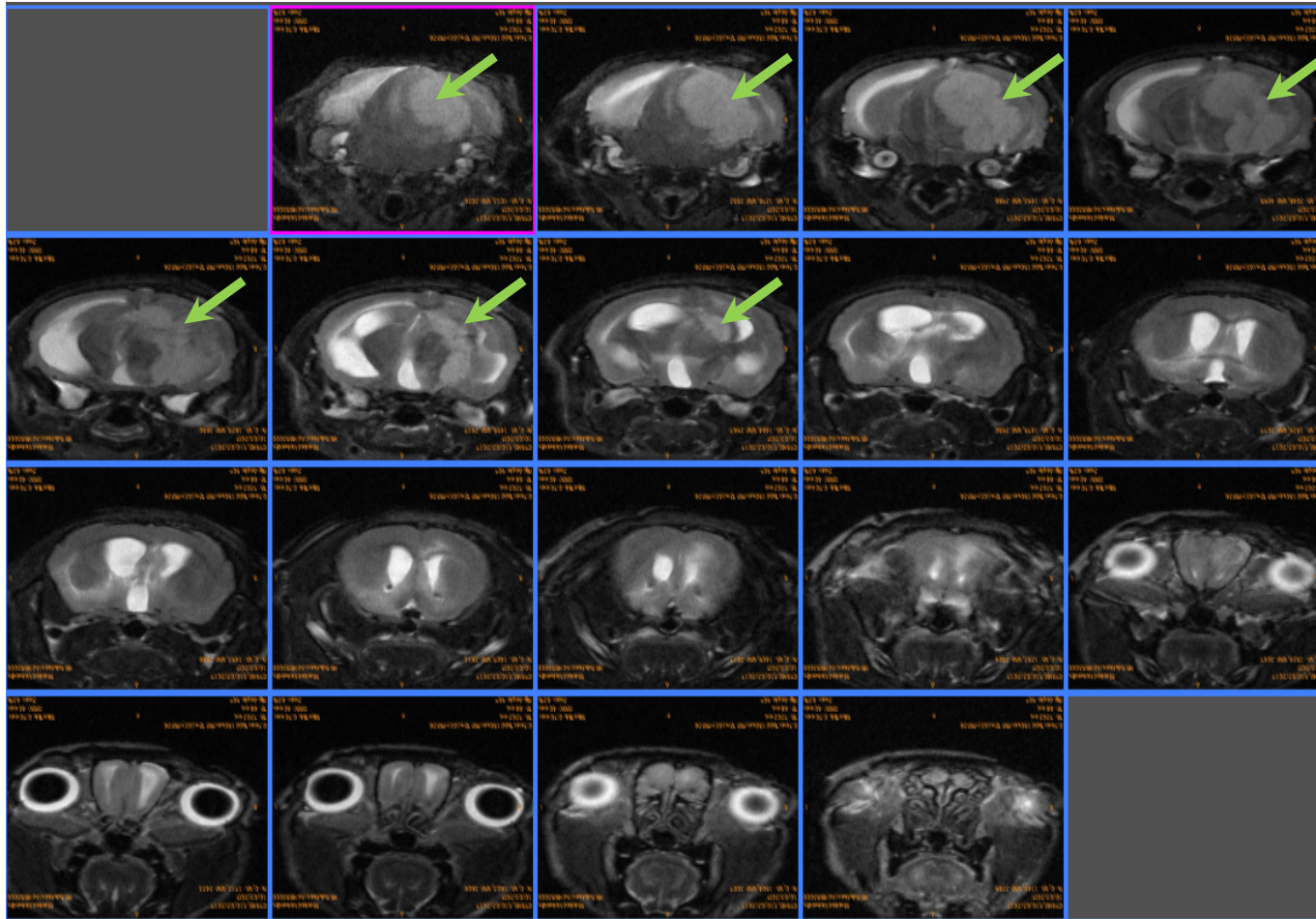
# Results: Nanoparticles Characterizations





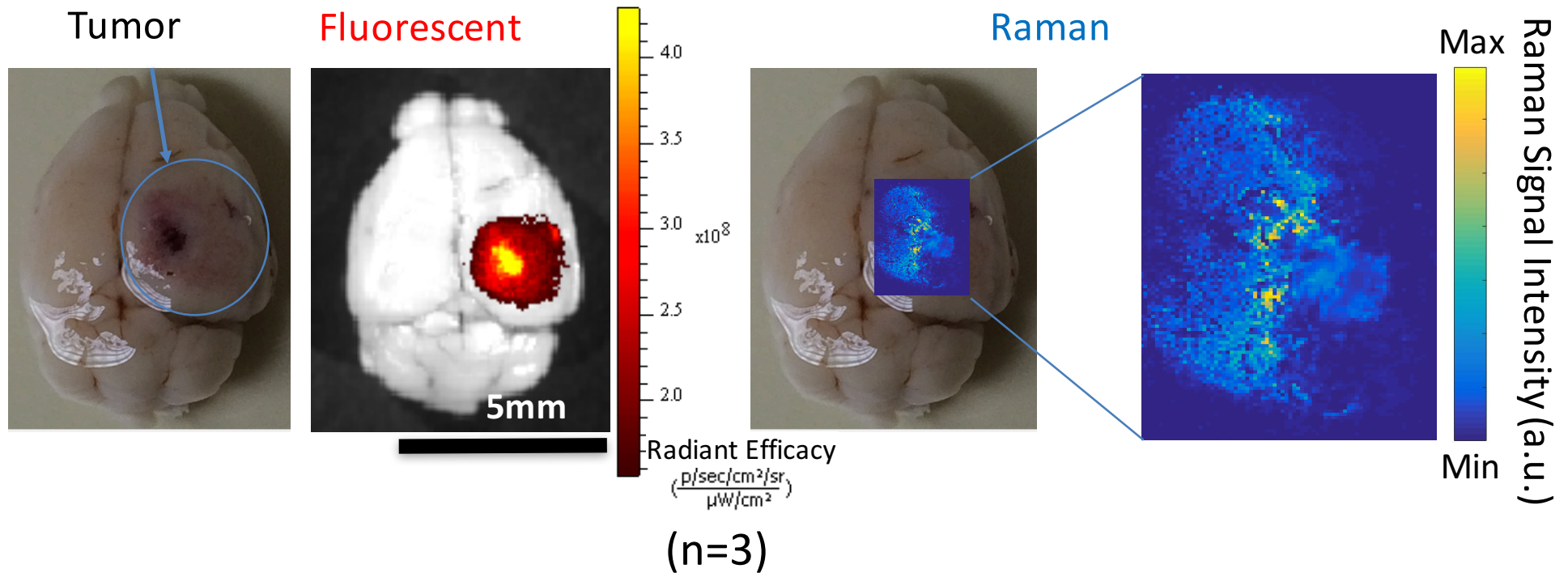
# Results: Mouse brain MRI

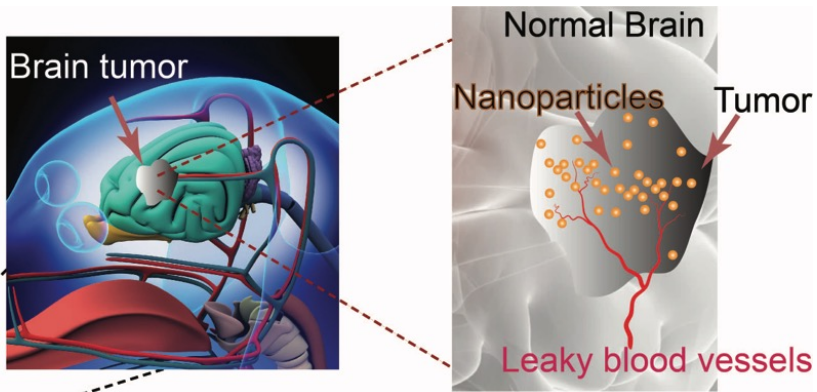
*(T2-weighted, U87 tumor)*



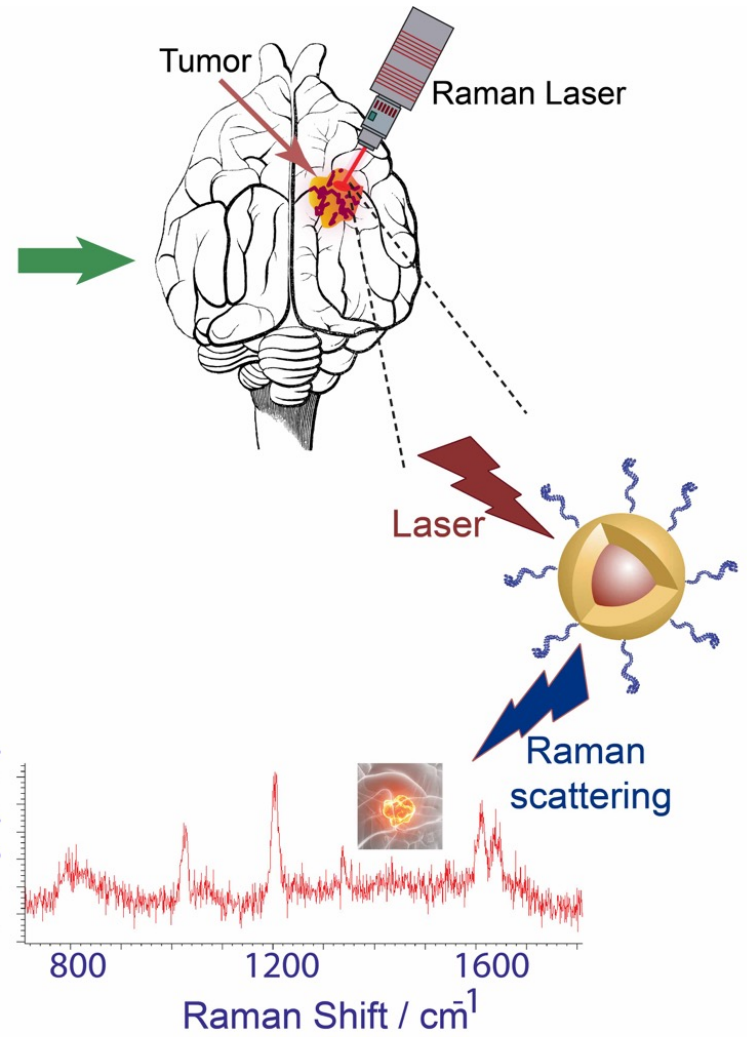
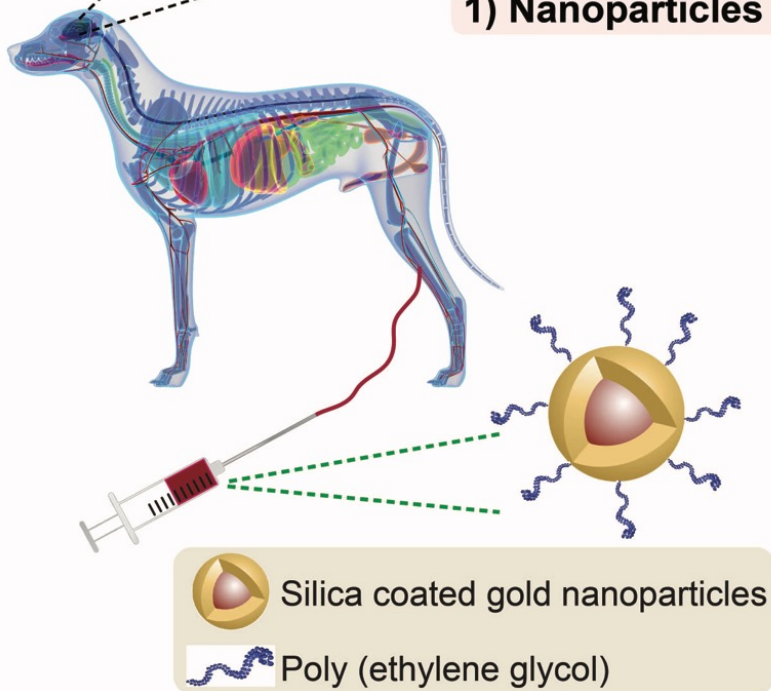
# Results: Intratumoral Diffusion of the Raman Nanoparticles

*(NPs volume and concentration ~ 2  $\mu$ L & 1 nM)*





### 1) Nanoparticles infusion



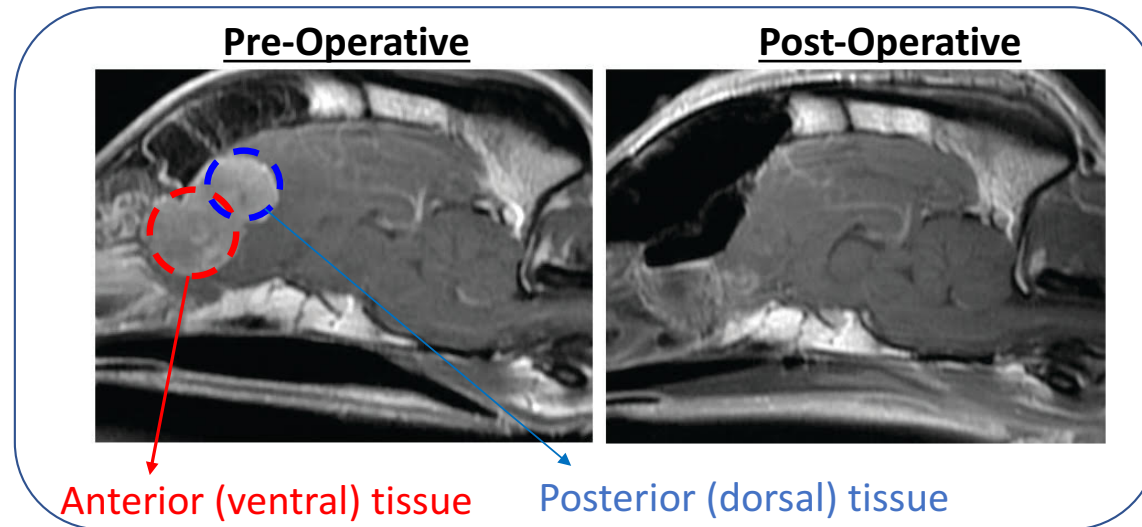
### 2) Raman spectroscopy/imaging

## Summary:

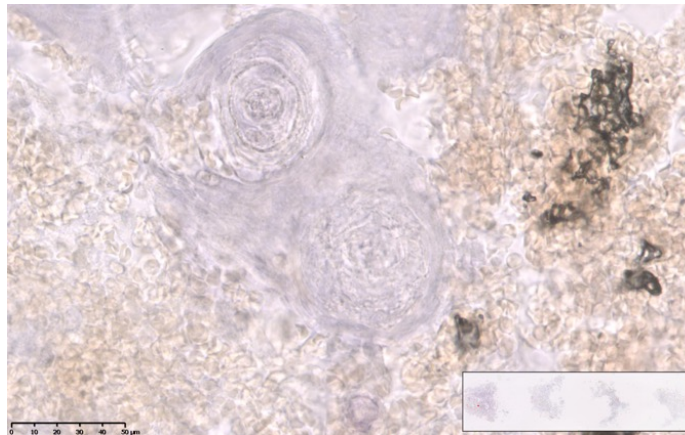
Case No.	Tumor	Dog's weight (kg)	Nanoparticles concentration (nM)	Nanoparticles volume (mL)
1	Oligodendroglioma	8.7	0.5	8.7
2	Psammomatous Meningioma	24.7	0.5	24.7
3	Fibrolastic Meningioma	20.3	0.5	20.3



# Dog Frontal Lobe Meningioma post-contrast T1 MRI and histology:

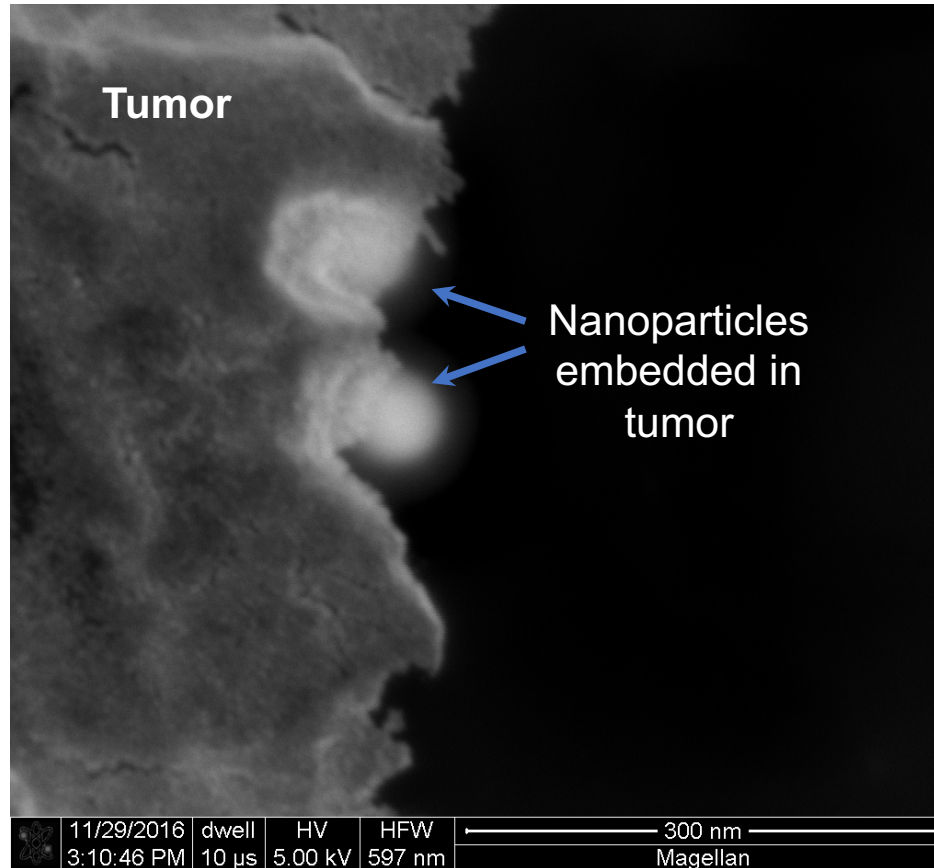


Histology of the tumor tissue  
(H&E)

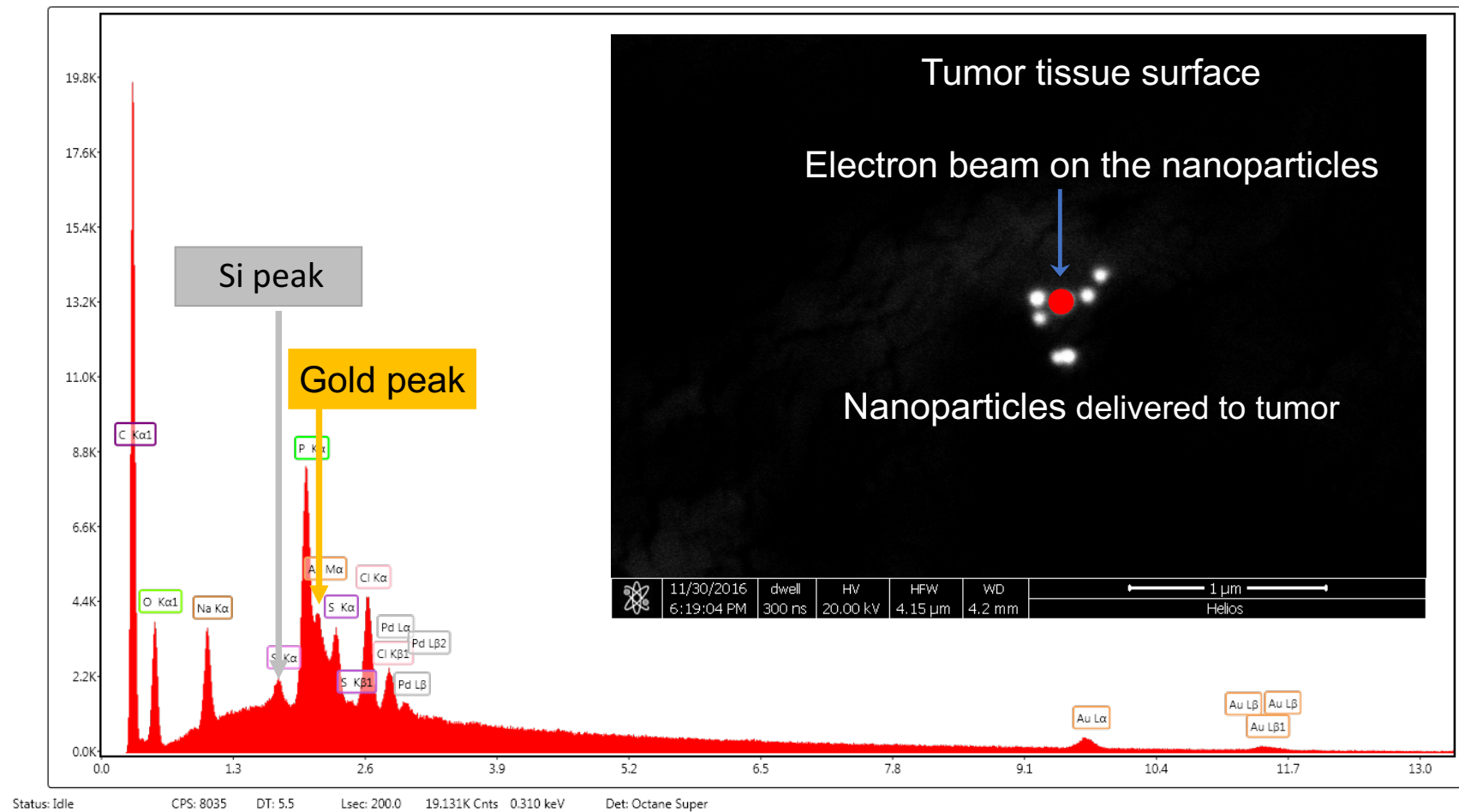


Whorls and Psammoma bodies (center) and dura mater (left, right, bottom)

# SEM at a tissue section, showing nanoparticles embedded in tumor tissue:



# Elemental Analyses Using Electronic Microscopy:



# Conclusions & Future Directions

- Surface enhanced Raman spectroscopy shows potential for simultaneous detection and ablation of brain tumors
- Nanoparticles systematic design appears to help their uniform intratumoral diffusion in brain microenvironment
- These are proof of concept data that require further investigation for clinical translation





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# Acknowledgements

Image: Raman nanoparticles diffused into the brain tumor

- Prof. Sanjiv Gambhir (Stanford, Radiology)
- Prof. Bob Sinclair (Stanford, Materials Science)
- Edwin Chang, Chirag Patel
- Steven Madsen, Ryan Miller, Demir Akin
- UC Davis Veterinary School
- Gambhir's lab



Stanford Cancer Imaging Training



Molecular Imaging  
Program at Stanford (MIPS)



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