Application of LEDs in Intravascular Photoacoustic Imaging

Electrical & Computer Engineering

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ECE 443 – Spring 2024

Medical Imaging History

- X-ray
- CT Scan
- MRI Scan
- Ultrasound
- Photoacoustic Imaging

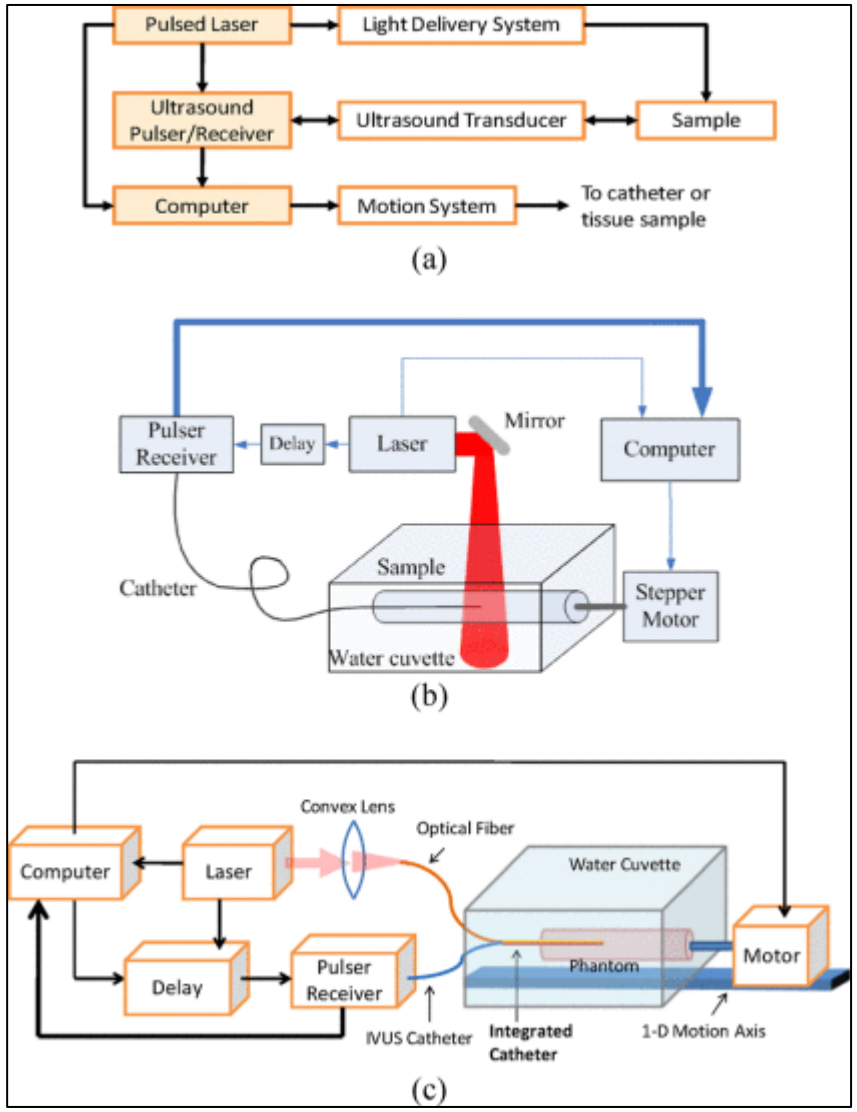
“I have seen my death” – Bertha Röntgen 1896

[2]

Personal Motivation

Photoacoustic Imaging

- Laser Generation
- Optical Absorption
- Thermal Excitation
- Ultrasonic Receiver



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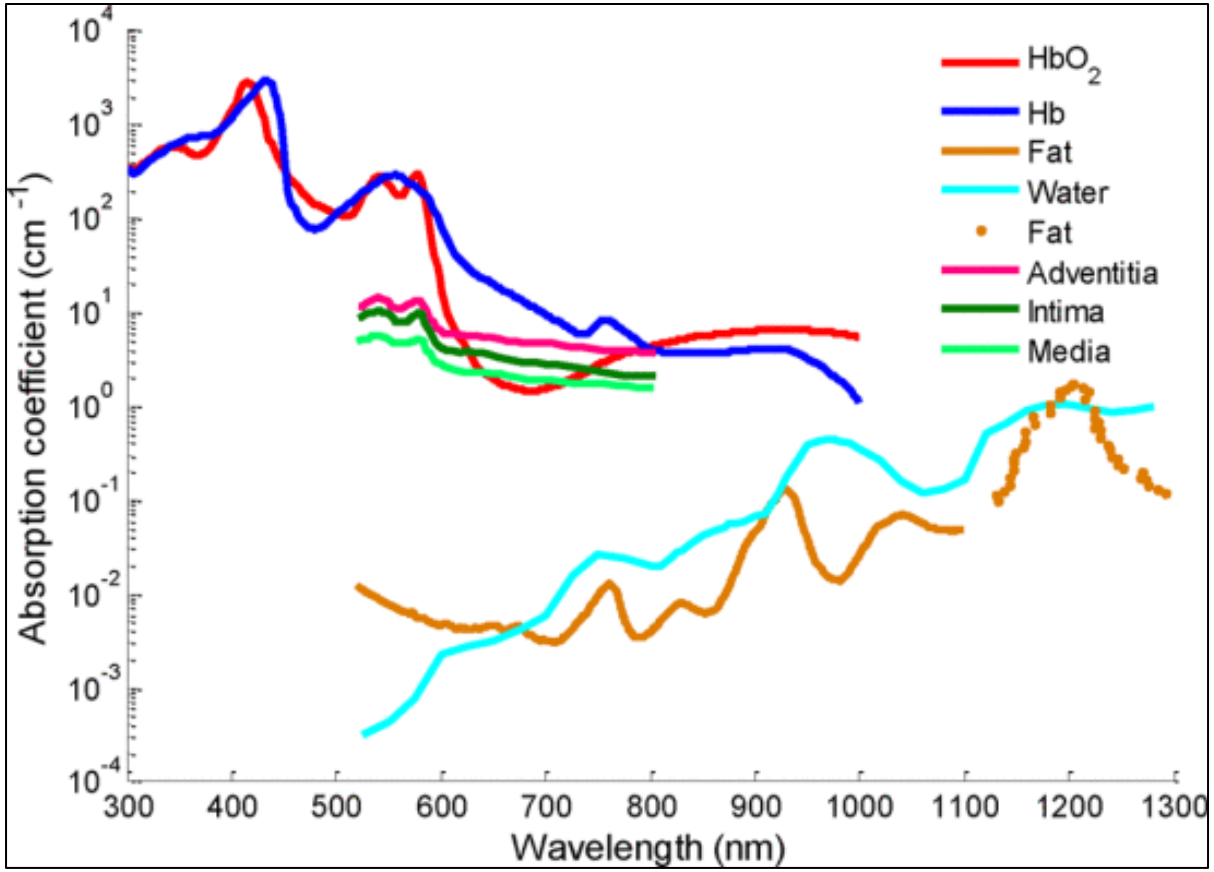
Special Properties

- Spectroscopic Imaging
- Molecular Imaging
- Tunable Penetration
- Metallic Imaging



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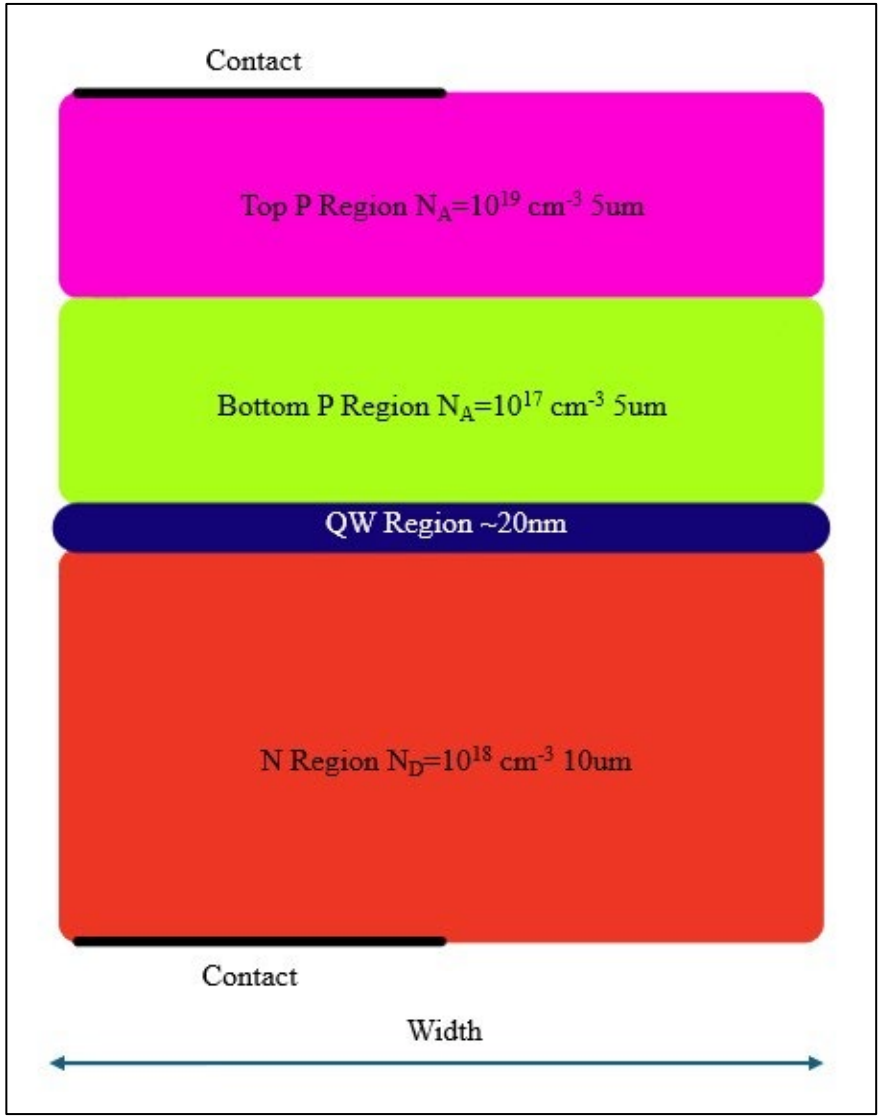
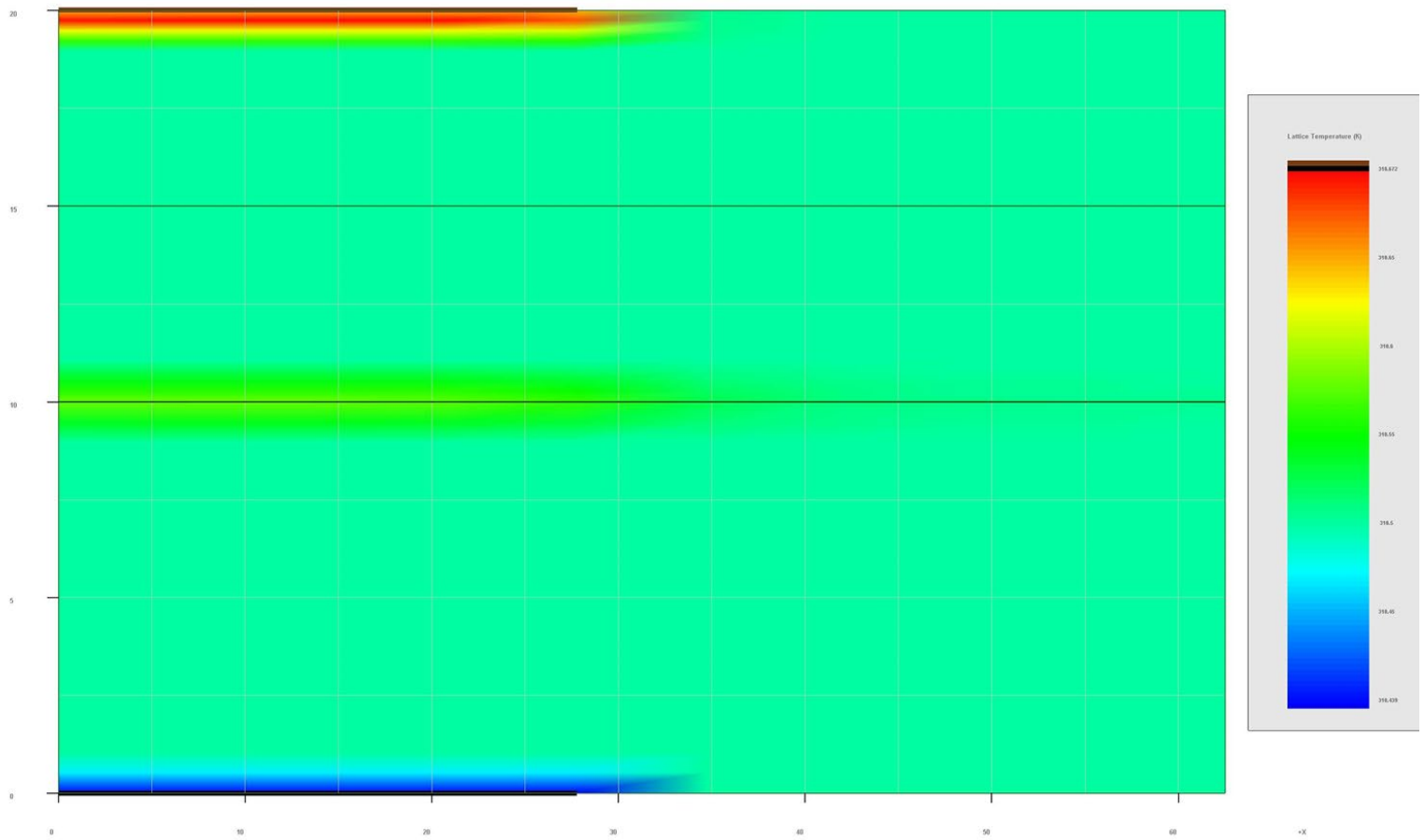
General Structure

Wavelength	Material
530 nm	$In_{0.32}Ga_{0.68}N$
630 nm	$In_{0.43}Ga_{0.57}N$
1070 nm	$In_{0.57}Ga_{0.43}As$
1210 nm	$In_{0.77}Ga_{0.23}As$



Sources

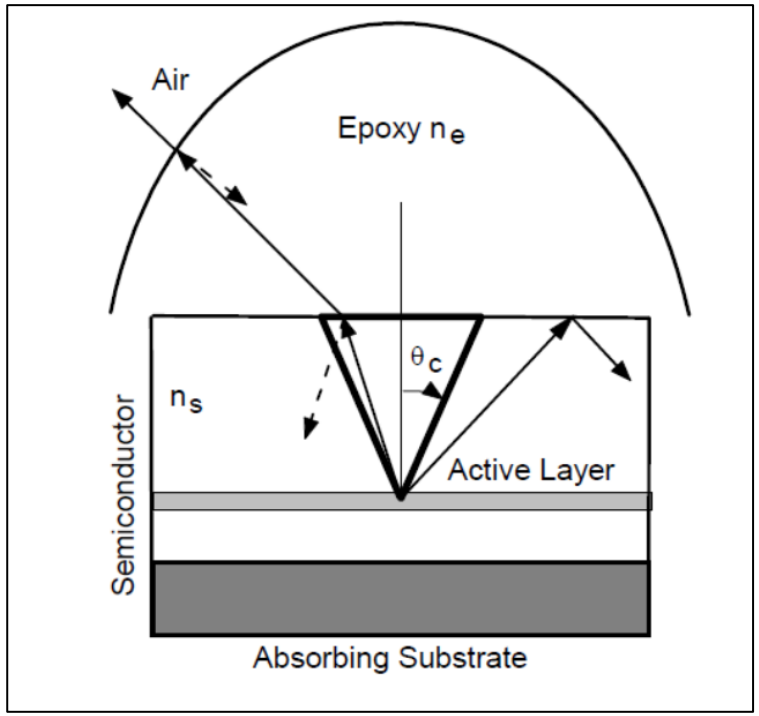
- Joule/Optical
- Recombination
- Radiative
- Heat Sink



Lattice Heat Distribution of λ=630nm W=62.5 um LED

Considerations

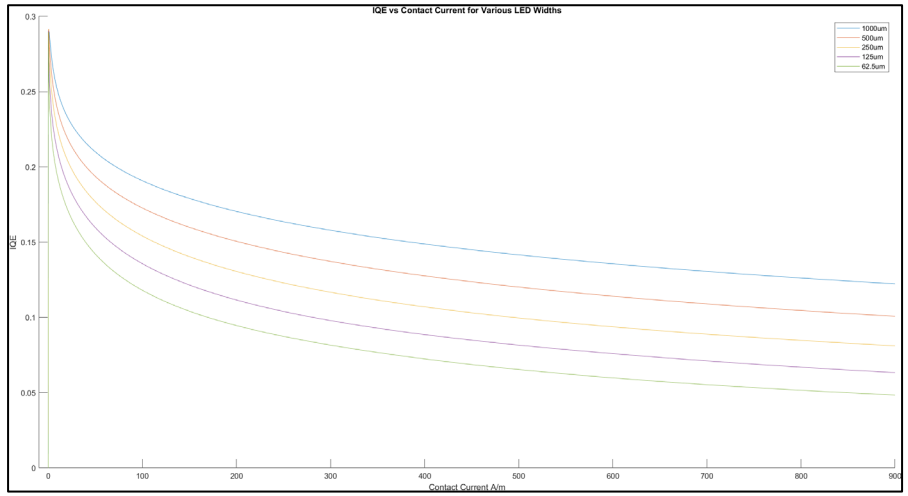
- High-Refractive Epoxy
- Thermal Isolation

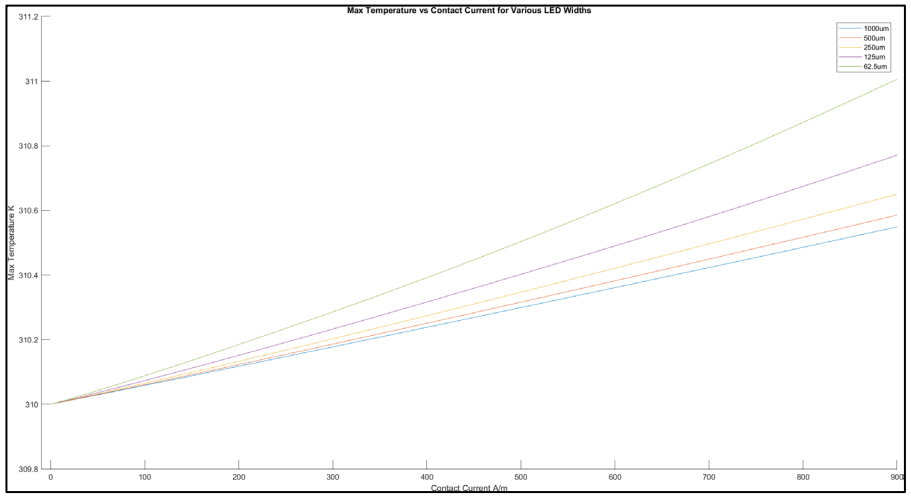


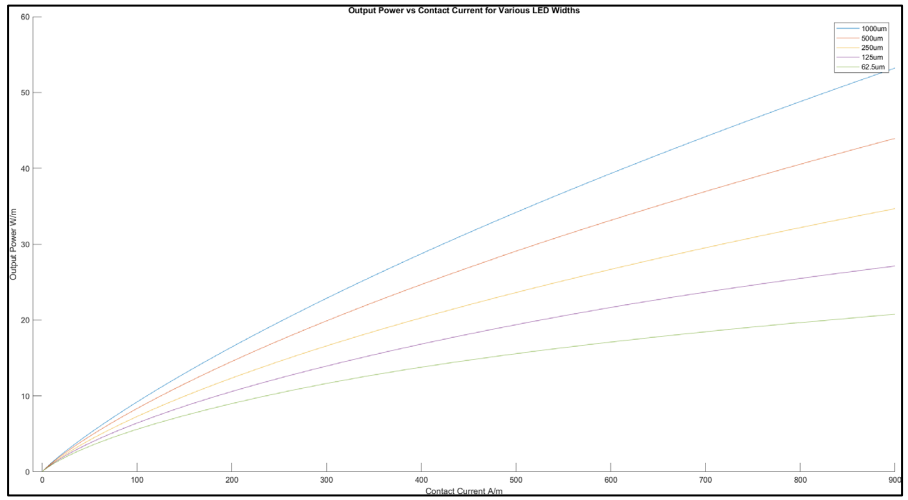
Bulk	Refractive Index	Epoxy	Refractive Index	Approximate LEE
GaN	2.38	ZnO	1.87	72%
GaAs	3.51	TiO2	2.28	45%

Conditions

- 0 to 900 A/m Contact Current
- Body Temperature ~310 K
- 62.5 to 1000 um LED width





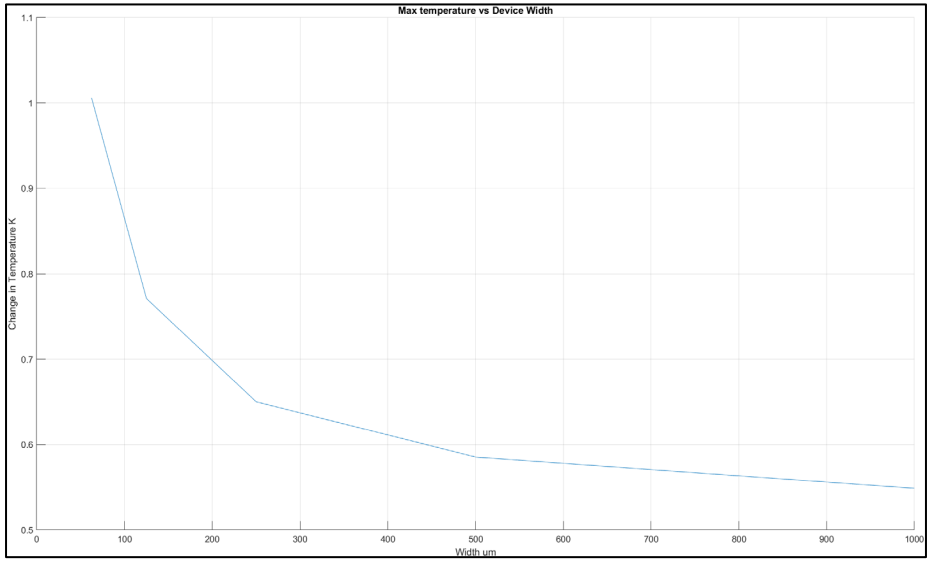


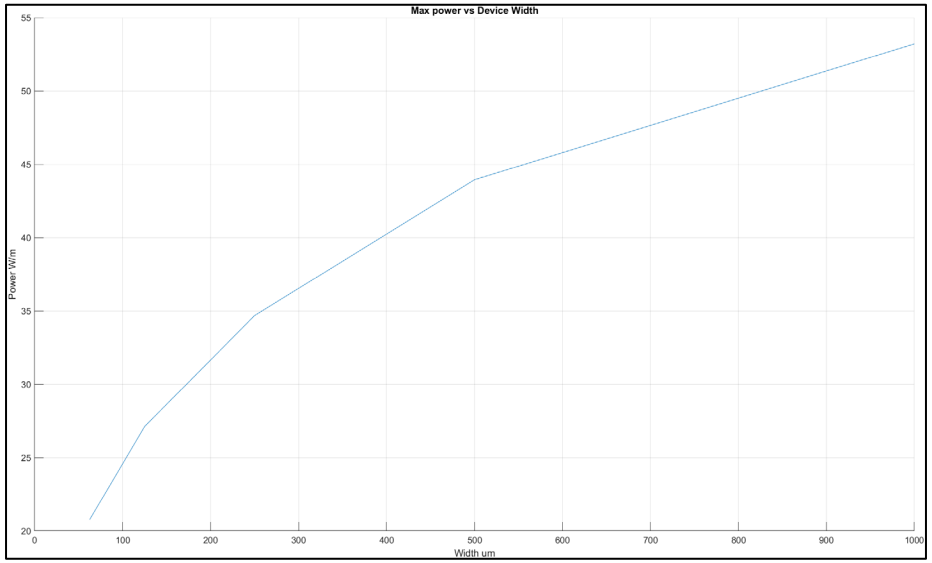
Current Trends

- IQE Decreases
- Power Increases
- Temperature Increases

Size Trends

- IQE Increases
- Power Increases
- Temperature Decreases*





Tabulated Results

Requirements

- Temperature < 315 K
- Energy > 0.5 uJ

Secondary Metrics

- Energy Composition
- Temperature Composition

λ (nm)	W (um)	T (K)	P (W/m)	50ns (uJ)	100ns (uJ)	500ns (uJ)
530	62.5	318.03	351.27	0.281	0.562	2.810
530	125.0	315.54	417.82	0.167	0.334	1.670
530	250.0	313.97	490.11	0.098	0.196	0.980
530	500.0	313.00	577.34	0.057	0.114	0.570
530	1000.0	312.42	665.62	0.033	0.066	0.330
630	62.5	318.69	219.20	0.175	0.350	1.750
630	125.0	316.19	269.57	0.107	0.214	1.070
630	250.0	314.62	323.69	0.064	0.128	0.640
630	500.0	313.08	452.38	0.045	0.090	0.450
630	1000.0	313.07	454.77	0.023	0.045	0.227
1070	62.5	310.67	99.97	0.008	0.016	0.080
1070	125.0	310.47	127.42	0.051	0.102	0.510
1070	250.0	310.42	158.54	0.032	0.064	0.320
1070	500.0	310.47	174.08	0.017	0.034	0.170
1070	1000.0	310.38	218.24	0.011	0.022	0.110
1210	62.5	311.01	20.76	0.017	0.034	0.170
1210	125.0	310.77	27.12	0.011	0.022	0.110
1210	250.0	310.65	34.68	0.007	0.014	0.070
1210	500.0	310.59	43.94	0.004	0.008	0.040
1210	1000.0	310.55	53.21	0.003	0.006	0.030

Design Choices

- Prefer 250 to 500um width
- High Thermal Conductivity Heat-Sink

Future Efforts

- Infrared Efficient LED
- 3D Heat-Sink
- Epoxy Temperature Modeling
- Transient Response

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References

[1] B. Wang, J. L. Su, A. B. Karpiouk, K. V. Sokolov, R. W. Smalling, and S. Y.Emelianov, “Intravascular photoacoustic imaging,” IEEE Journal of Selected Topicsin Quantum Electronics, vol. 16, no. 3, p. 588–599, 2010. [Online]. Available: http://dx.doi.org/10.1109/JSTQE.2009.2037023

[2] Panchbhai and A. S., “Wilhelm conrad r¨ontgen and the discovery of x-rays: Revisited aftercentennial,” Journal of Indian Academy of Oral Medicine and Radiology, vol. 27, no. 1,p. 90, 2015. [Online]. Available: http://dx.doi.org/10.4103/0972-1363.167119