# On-Chip Photonics - $Al_2O_3$ and $Al_2O_3:Er^{3+}$ as a Low-Loss Waveguide Platform for Development of Amplifiers and Lasers

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Compact laser sources are crucial for the next generation of photonic integrated circuits, where bulky mechanical components and other optical bench top systems can be realized on a single tiny chip. Similarly, biological sensing, environmental real-time monitoring and telecommunications all benefit from the advances seen in on-chip photonic components, in particular, active devices such as the amplifier and laser which have significant challenges in being implemented on a silicon substrate. To overcome these challenges, rare earth elements embedded in various oxide matrices have been demonstrated as viable hosts for optical amplification and lasing, and when integrated on a silicon substrate, enable low-cost devices compatible with complementary metal-oxide-semiconductor (CMOS) manufacturing. The study of Erbium doped Aluminium Oxide ($Al_2O_3:Er^{3+}$) has attracted significant interest from the research community due to its high solubility for rare-earth ions, wide optical transparency, and capability to be integrated as a hybrid coating or patterned into waveguides on a Si substrate using conventional fabrication techniques [1]. Optical gain has been demonstrated in patterned $Al_2O_3:Er^{3+}$ waveguide spiral amplifiers [2], lasers have been realized in microresonators on-chip [3], and a monolithically integrated $Al_2O_3:Er^{3+}$-$Si_3N_4$ waveguide amplifier has demonstrated 8x40 Gbps of WDM amplification [4]. These results point towards $Al_2O_3$ as an ideal candidate for further research into the development of amplifiers and lasers for photonic integrated circuits (PIC). Here we demonstrate an overview of our recent work towards very low-loss waveguides in the $Al_2O_3$ platform with broadband operation. A summary of recent results and current prospects with recommendations for improvement on $Al_2O_3:Er^{3+}$ waveguide amplifiers will be discussed, as well as lifetime measurements for a variety of deposited films with insights into ideal host conditions for erbium dopants in amorphous and polycrystalline material.

## References

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