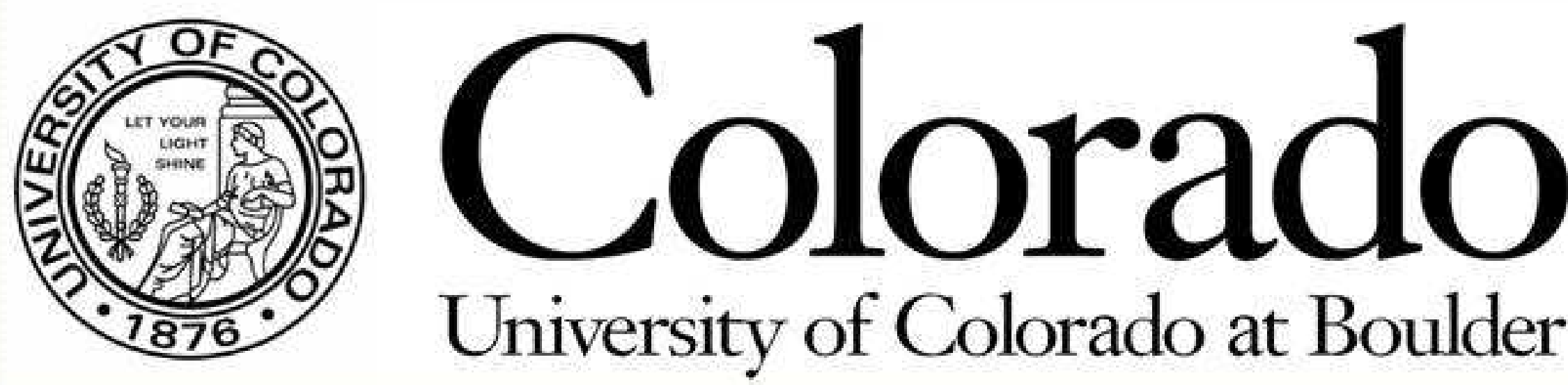


A Systematic Study of Techniques to Directly Measure the Saturable Absorption of Graphene

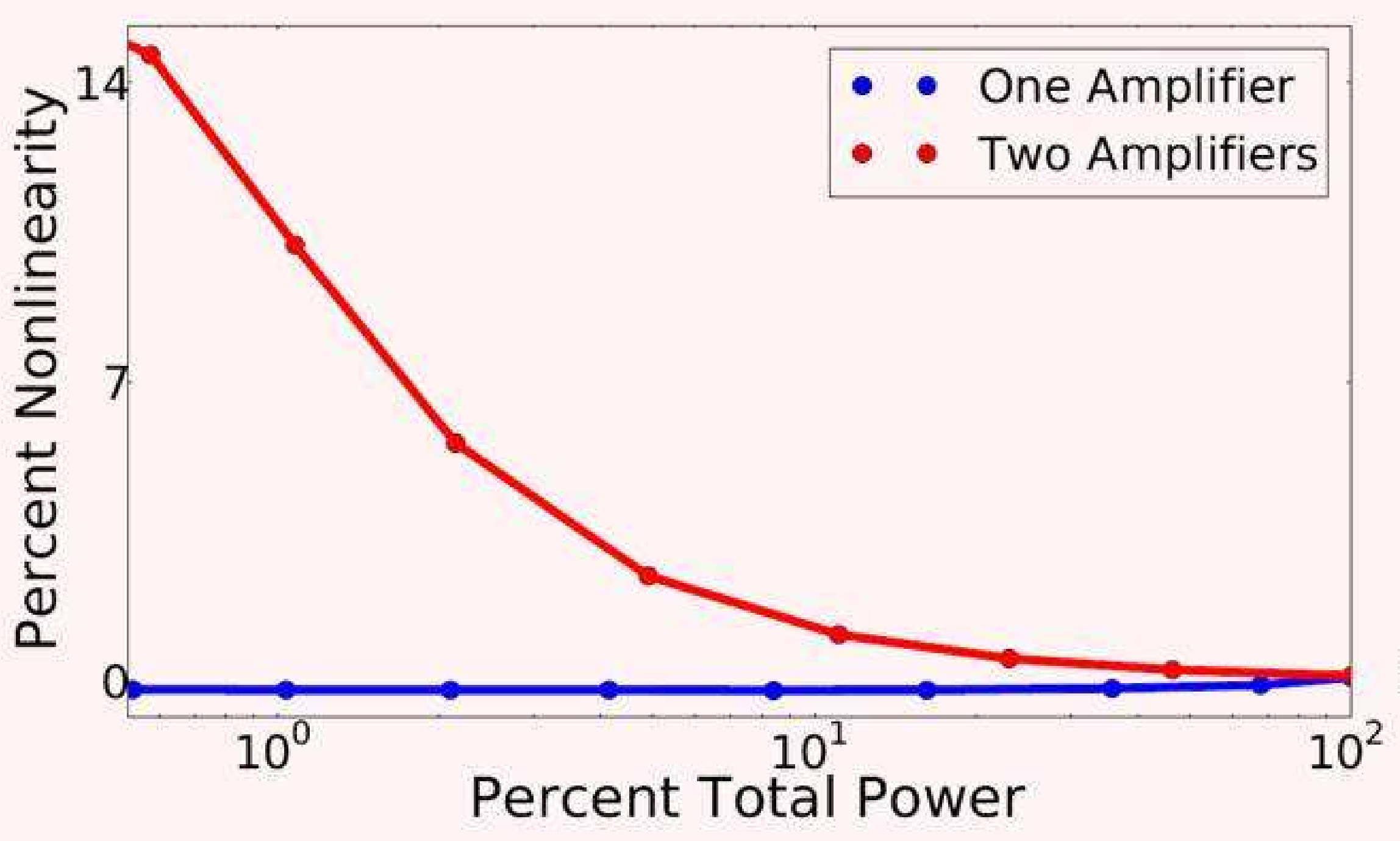
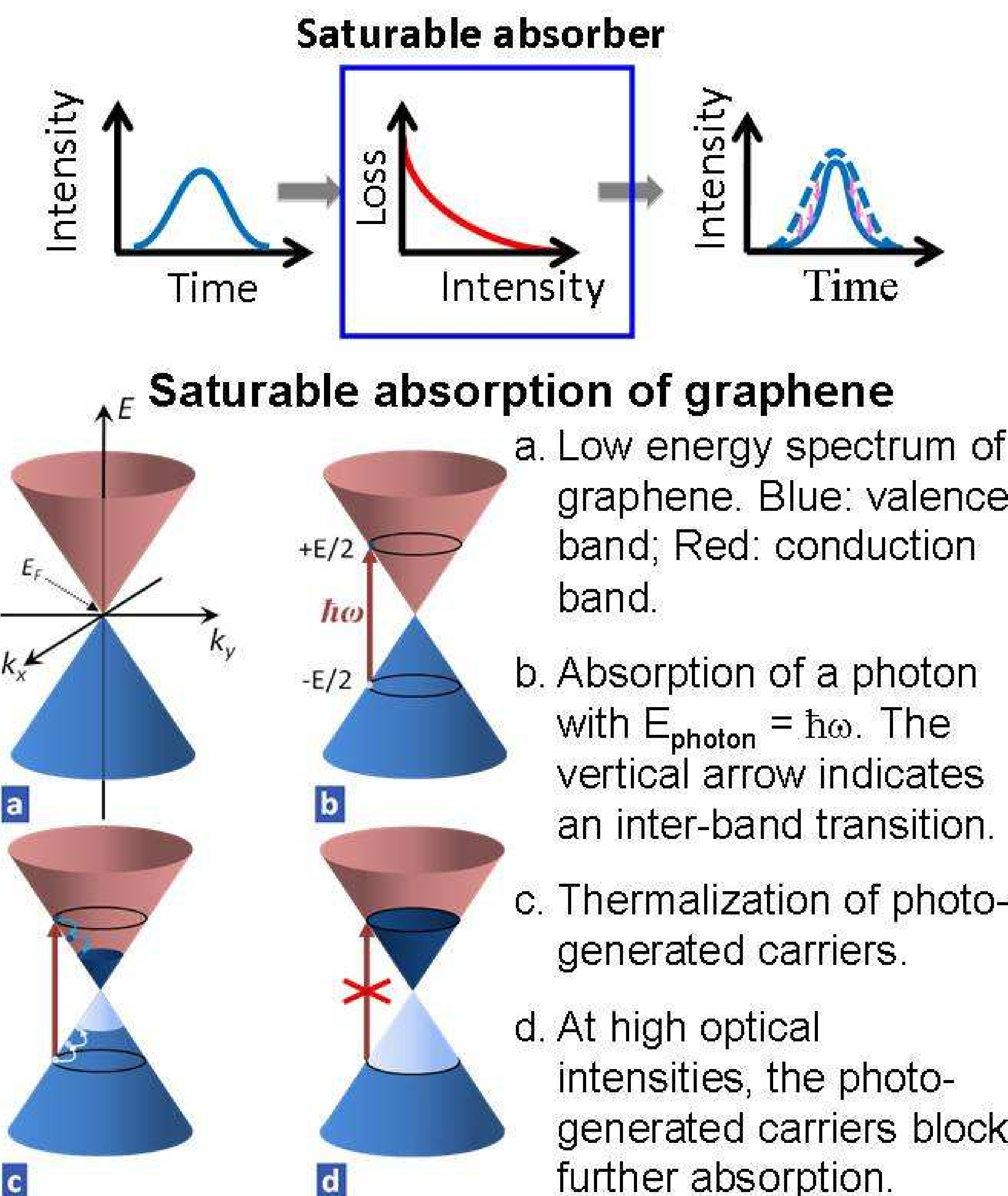


J. M. Miller, C.-C. Lee, T. R. Schibli, Department of Physics
jonah.miller@colorado.edu, <http://spot.colorado.edu/~trs/>

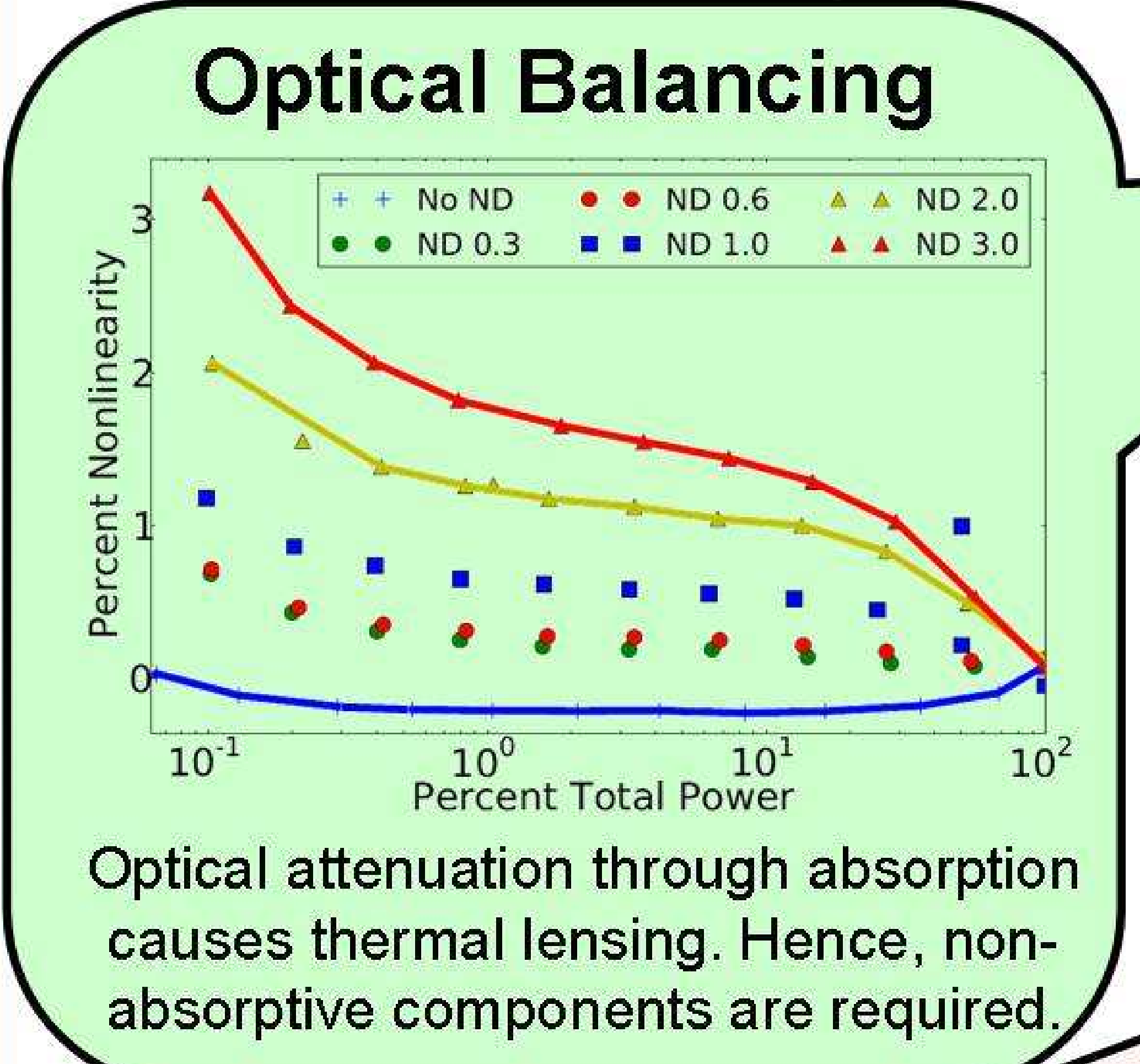
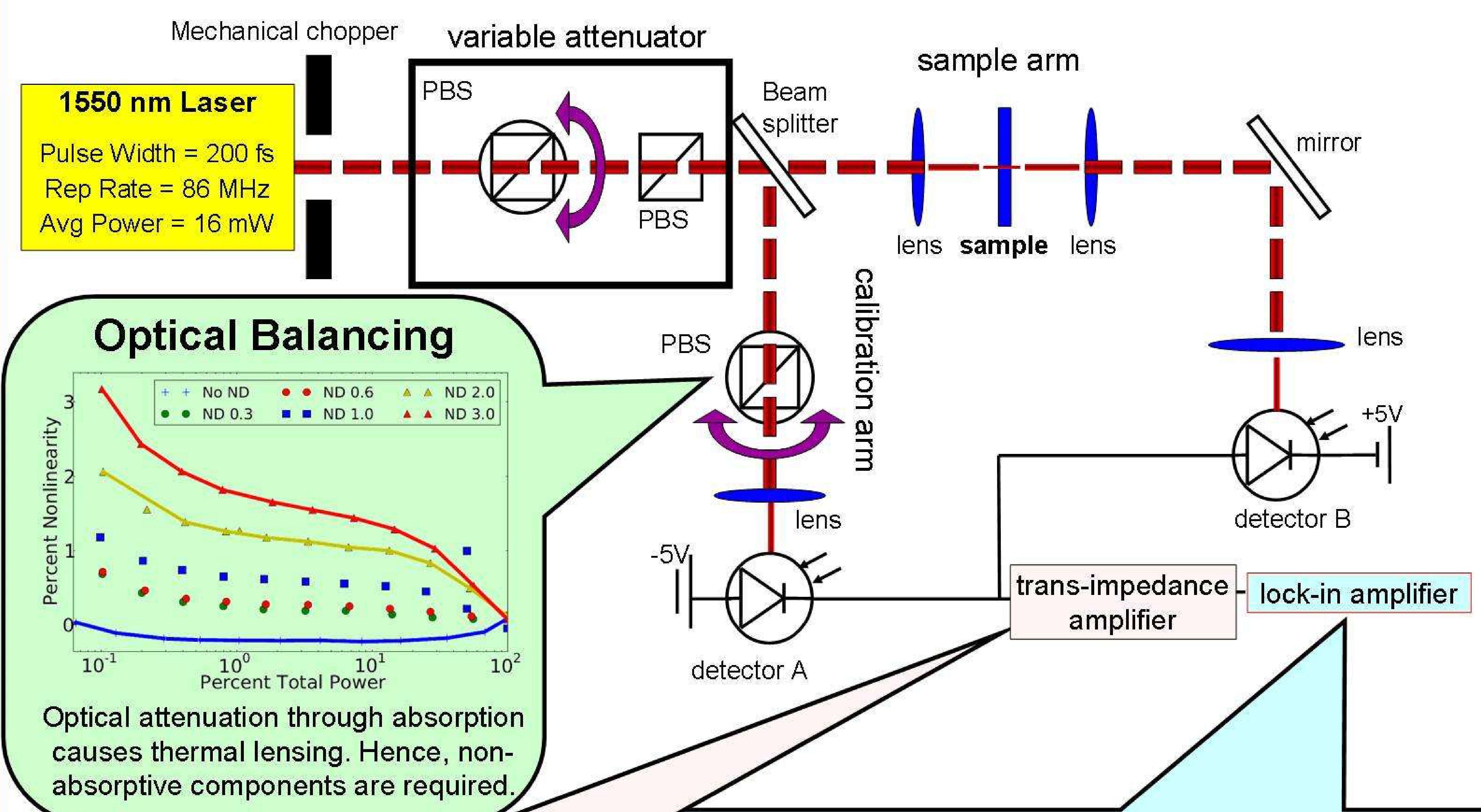


Motivation

Graphene's electrical and mechanical properties have been well explored. However, there are many as of yet untapped applications for this novel material. For instance, to take advantage of graphene's potential as a saturable optical absorber, it is absolutely essential to characterize its optical properties precisely.



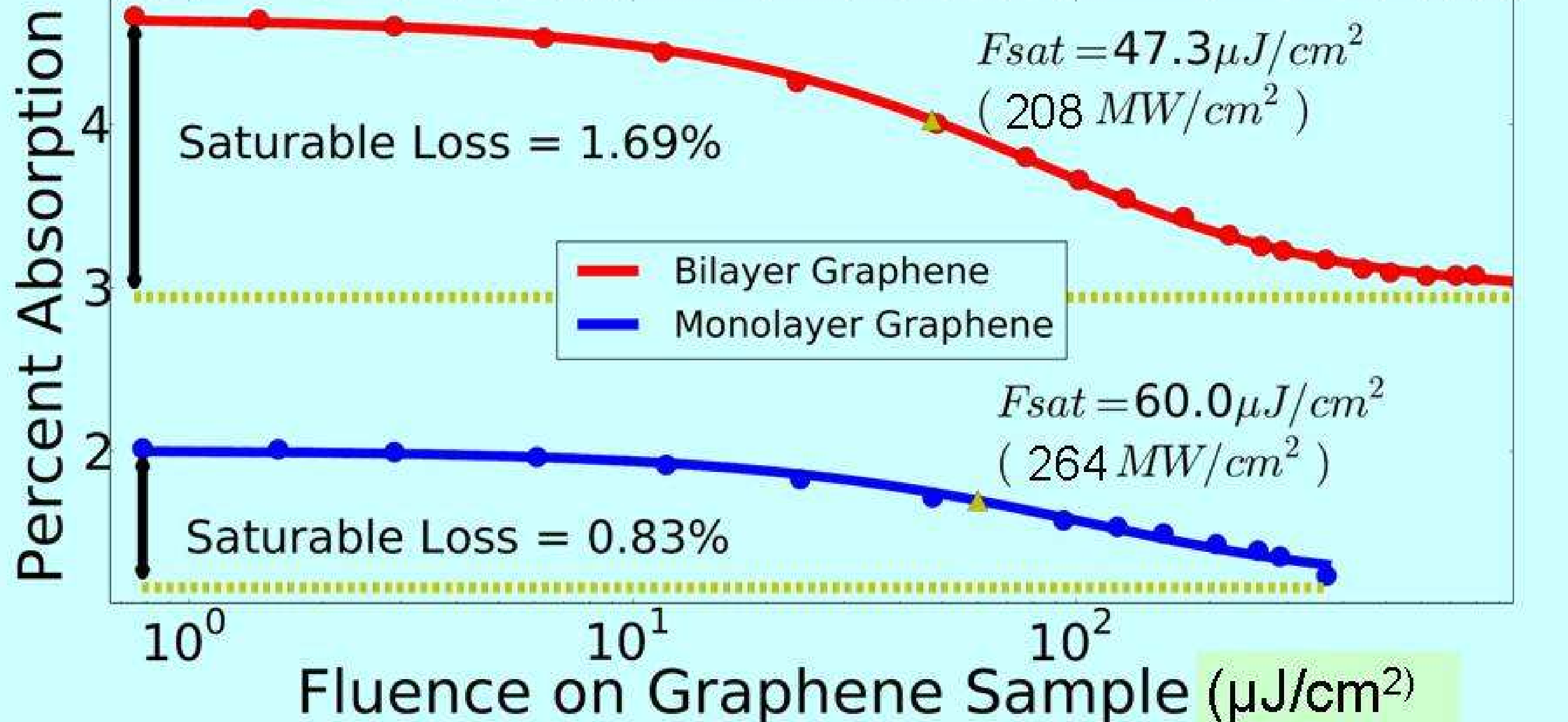
Balanced Detection



Maintaining the Dynamic Range

A significant source of nonlinearity comes from the electronics themselves. The differences between two supposedly identical amplifiers can cause large variations over a dynamic range of three orders of magnitude. Instead one should electrically subtract the signals from the two photo detectors and amplify the subtracted signal with a single amplifier.

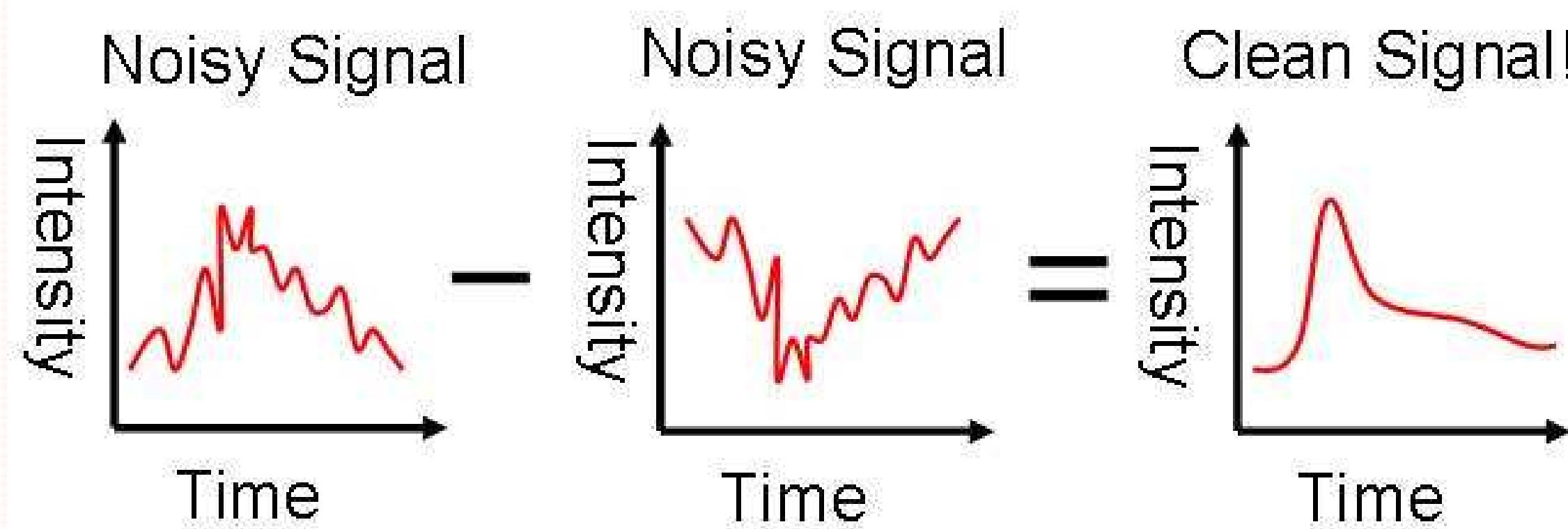
The Results



With attention to all sources of systematic error, this technique can measure nonlinear absorption to an accuracy better than 0.1% after calibration over a dynamic range of over three orders of magnitude.

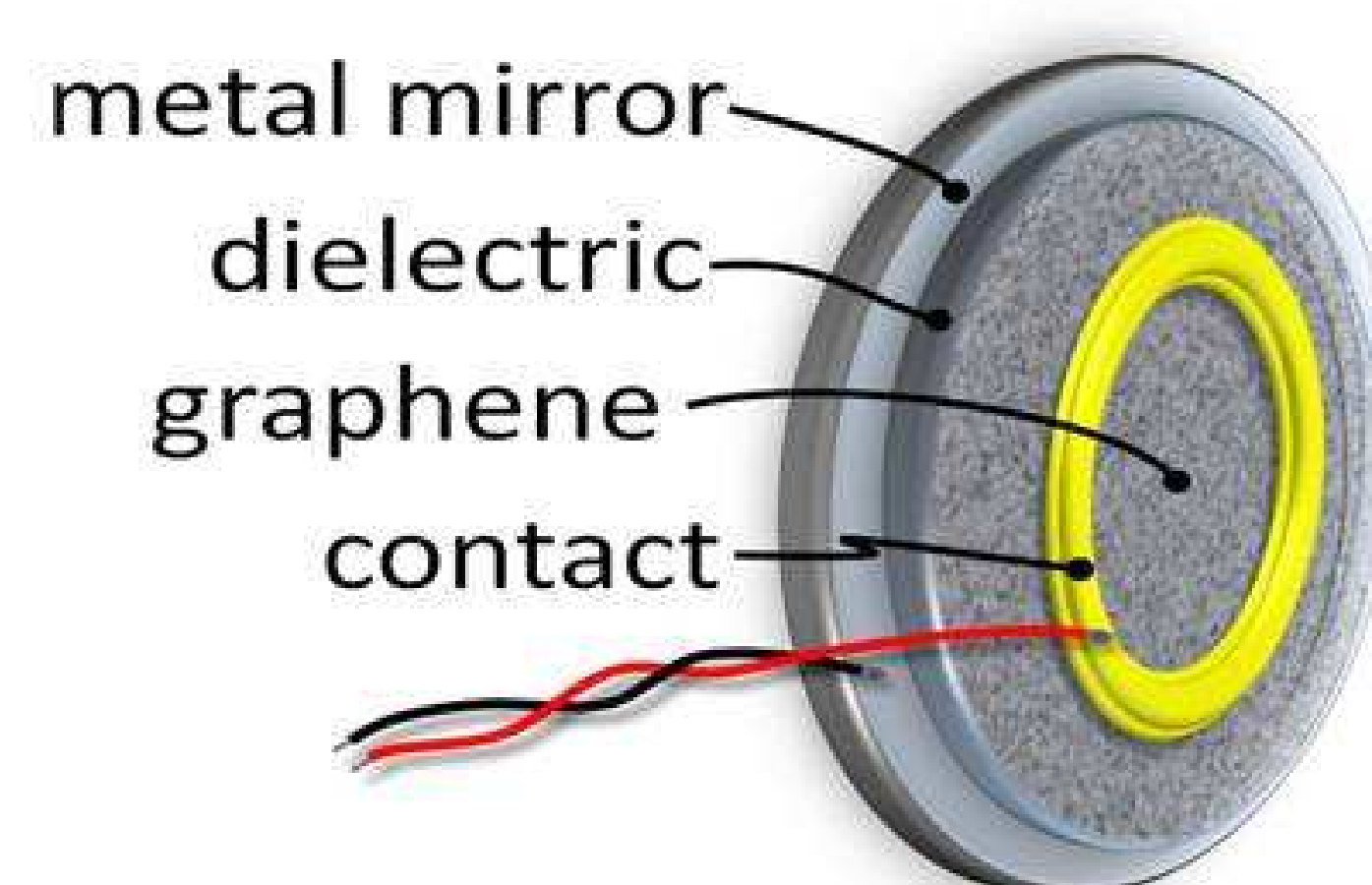
The Idea

Nonlinear absorption can be small. To measure it over a large dynamic range can be very difficult. Balanced Detection offers a solution while reducing the noise^{1,2}.



Balanced detection removes common-mode noise from the signal. In our specific case, one detector measures the optical absorption signal plus the laser-noise, the other one measures only the laser noise. The difference between the two is the actual signal without the noise.

The Future



Optical devices that utilize graphene's nonlinear absorption for passive mode-locking or active laser stabilization

References

1. Haiml, M et al. "Optical Characterization of Semiconductor Saturable Absorbers." *Applied Physics B* 79, 331-339 (2004).
2. Maas, D. J. H. C et al. "High Precision Optical Characterization of Semiconductor Saturable Absorber Mirrors." *Optics Express* 7571 (2008).