The echo of superconductivity: Higgs Spectroscopy of Superconductors in non-equilibrium

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Time-resolved pump-probe experiments recently attracted great interest, since they allow to detecting hidden states and they provide new information on the underlying dynamics in solids in real time. With the observation of a Higgs mode in superconductors it is now possible to investigate the superconducting order parameter directly. Recently, we have established a theory for superconductors in non-equilibrium, for example in a pump-probe experiment. Using the Density-Matrix-Theory (DMT) we have developed an approach to calculate the response of conventional and unconventional superconductors in a time-resolved experiment. In particular, DMT method is not restricted to small timescales; in particular it provides a microscopic description of the quench, and also allows also the incorporation of phonons. Furthermore, we employ DMT to time-resolved Raman scattering experiments and make predictions for 2-band superconductors. Very recently, we have focused on the theory for order parameter amplitude ('Higgs') oscillations which are the realization of the Higgs mode in superconductors [1]. New predictions are made for the Leggett mode in 2-band superconductors. Finally, we address the question of induced superconductivity in non-equilibrium. Our prediction has been recently confirmed experimentally.

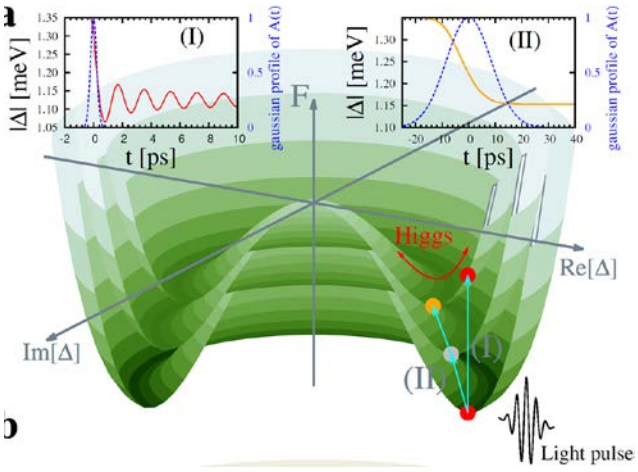

Fig. 1. Mexican hat potential of the Free Energy in non-equilibrium as a function of time. Only in case (I), using a short pulse, Higgs oscillations can be generated.

REFERENCES

[1] H. Krull *et al*., Nat. Comm. **7**, 11921 (2016).