Theory of light-enhanced superconductivity

arXiv:1505.07575

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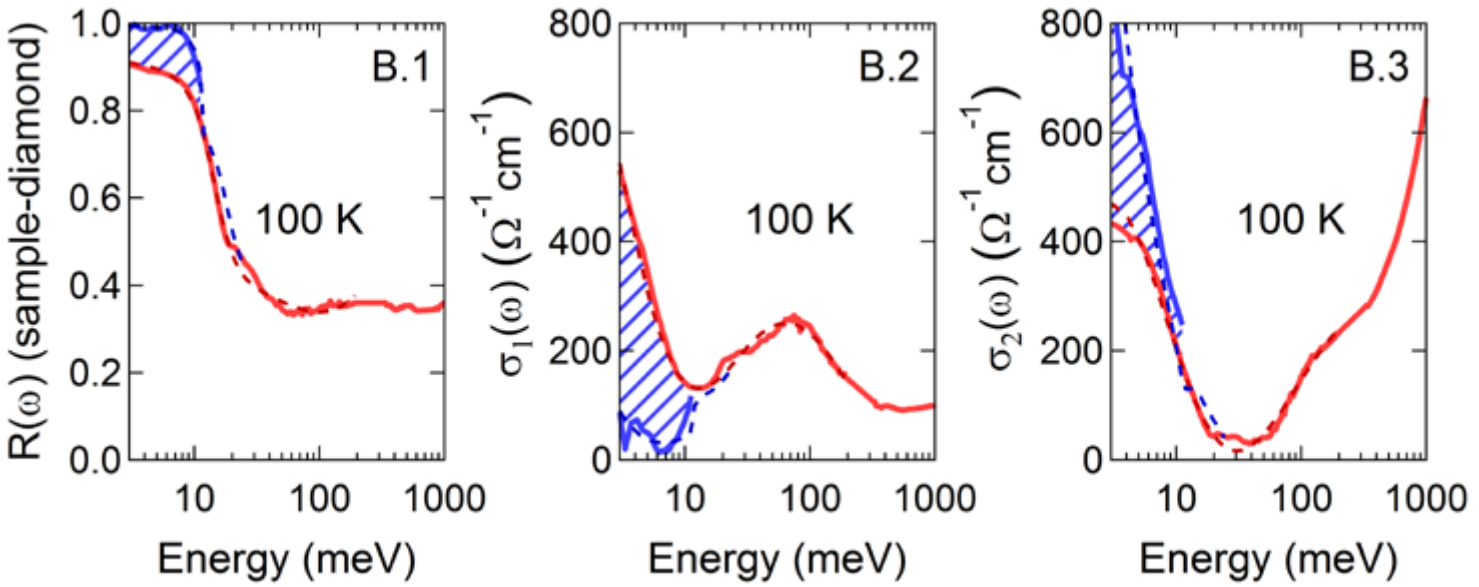
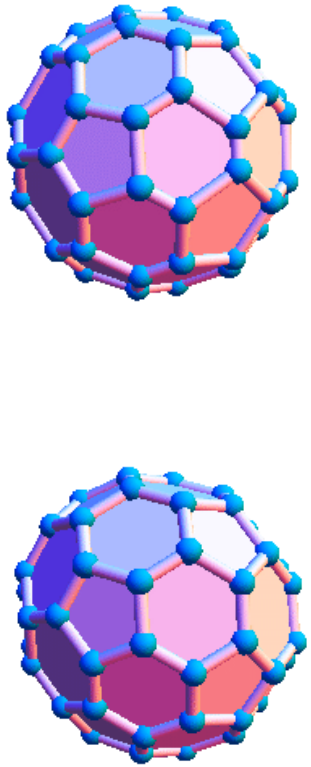
Max Planck Institute for the Structure and Dynamics of Matter

Light-induced superconductivity?

„Possible light-induced superconductivity in K3C60 at high temperature“

M. Mitrano et al., Nature 530, 461 (2016)





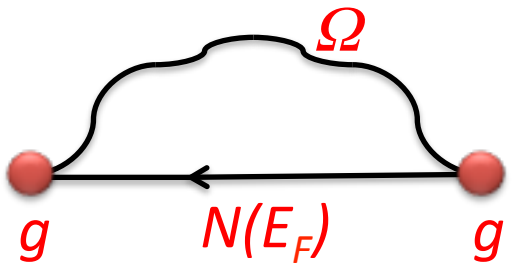
How to enhance boson-mediated SC?

- BCS theory – plain vanilla SC (weak coupling)

$$\Delta \approx 2\hbar\Omega_c \exp(-1/V_0 N(E_F))$$

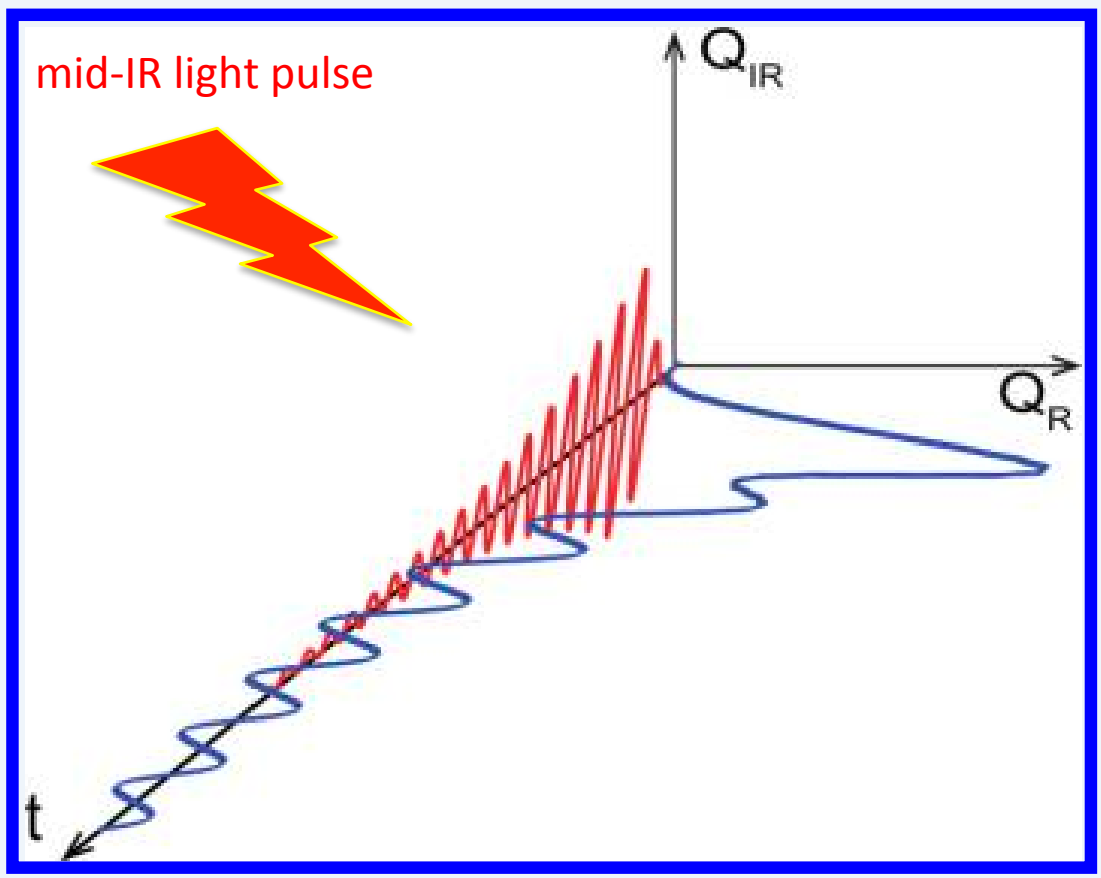
  - effective attraction $V_0 \sim g^2/(\hbar\,\Omega)$
  - e-boson coupling g
  - boson frequency Ω
  - **electronic DOS $N(E_F)$**

$\Sigma =$



Migdal-Eliashberg theory
boson-mediated pairing

Nonlinear phononics



$$\ddot{Q}_{IR} + \Omega_{IR}^2 Q_{IR} = \frac{e^* E_0}{\sqrt{M_{IR}}} \sin(\Omega_{IR} t) F(t)$$

$$\ddot{Q}_{RS} + \Omega_{RS}^2 Q_{RS} = A Q_{IR}^2$$

Rectification of a second (Raman) phonon via coherent driving of a first (IR) phonon

Enhancement of SC via enhanced DOS at Fermi energy?

„Nonlinear phononics“

M. Först et al., Nature Physics 7, 854 (2011)

A. Subedi, A. Cavalleri, A. Georges, PRB 89, 220301R (2014) *M. Knap et al., arXiv:1511.07874*

Model and Method

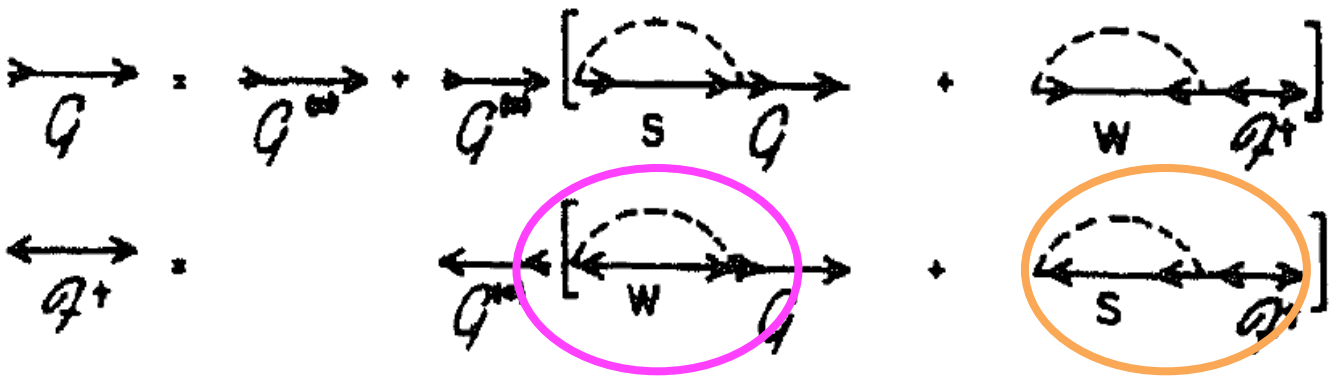
$$\mathcal{H} = \sum_{\boldsymbol{k}\sigma} \epsilon(\boldsymbol{k},t) c^\dagger_{\boldsymbol{k}\sigma} c_{\boldsymbol{k}\sigma} + \sum_{\boldsymbol{q},\gamma} \Omega_\gamma b^\dagger_{\boldsymbol{q},\gamma} b_{\boldsymbol{q},\gamma} - \sum_{\boldsymbol{q},\gamma,\sigma} g_\gamma c^\dagger_{\boldsymbol{k}+\boldsymbol{q}\sigma} c_{\boldsymbol{k}\sigma} \left(b_{\boldsymbol{q},\gamma} + b^\dagger_{-\boldsymbol{q},\gamma} \right)$$

electrons (2D) + phonons + el-ph coupling (Holstein)

Migdal-Eliashberg, nonequilibrium Keldysh Green functions:

normal

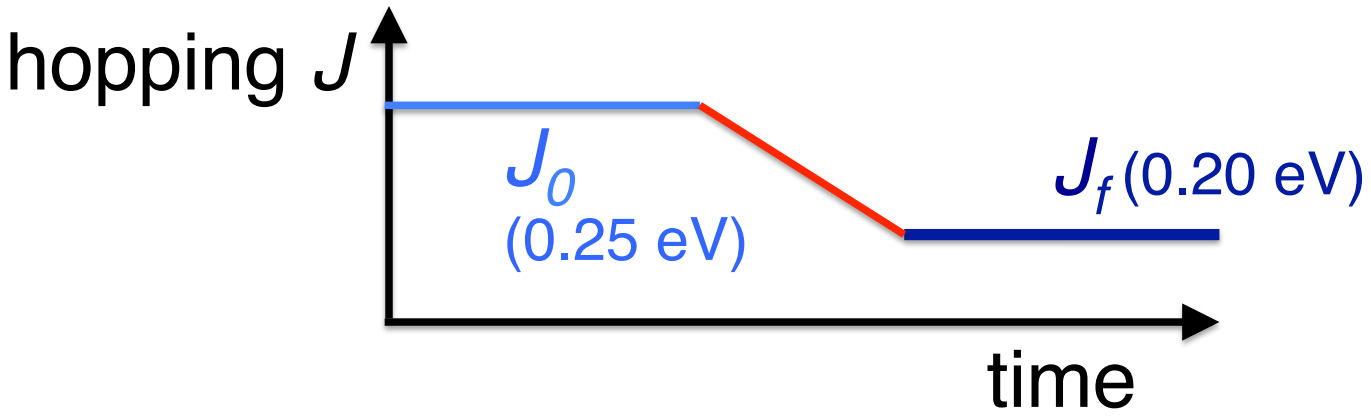
anomalous

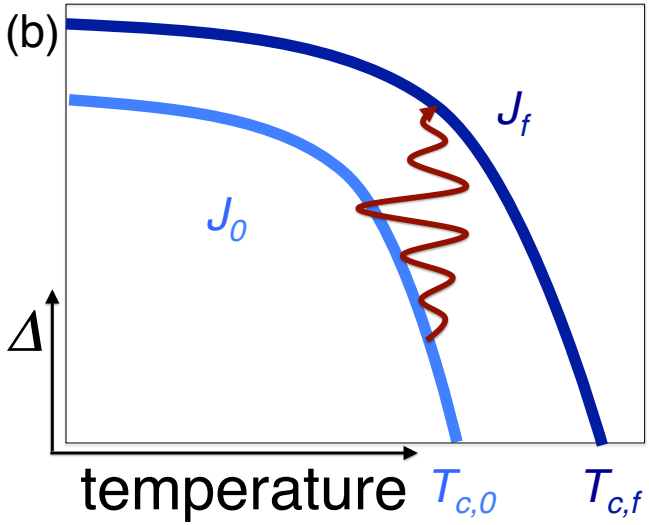


order parameter Δ, condensate dynamics

el-ph single-particle scattering

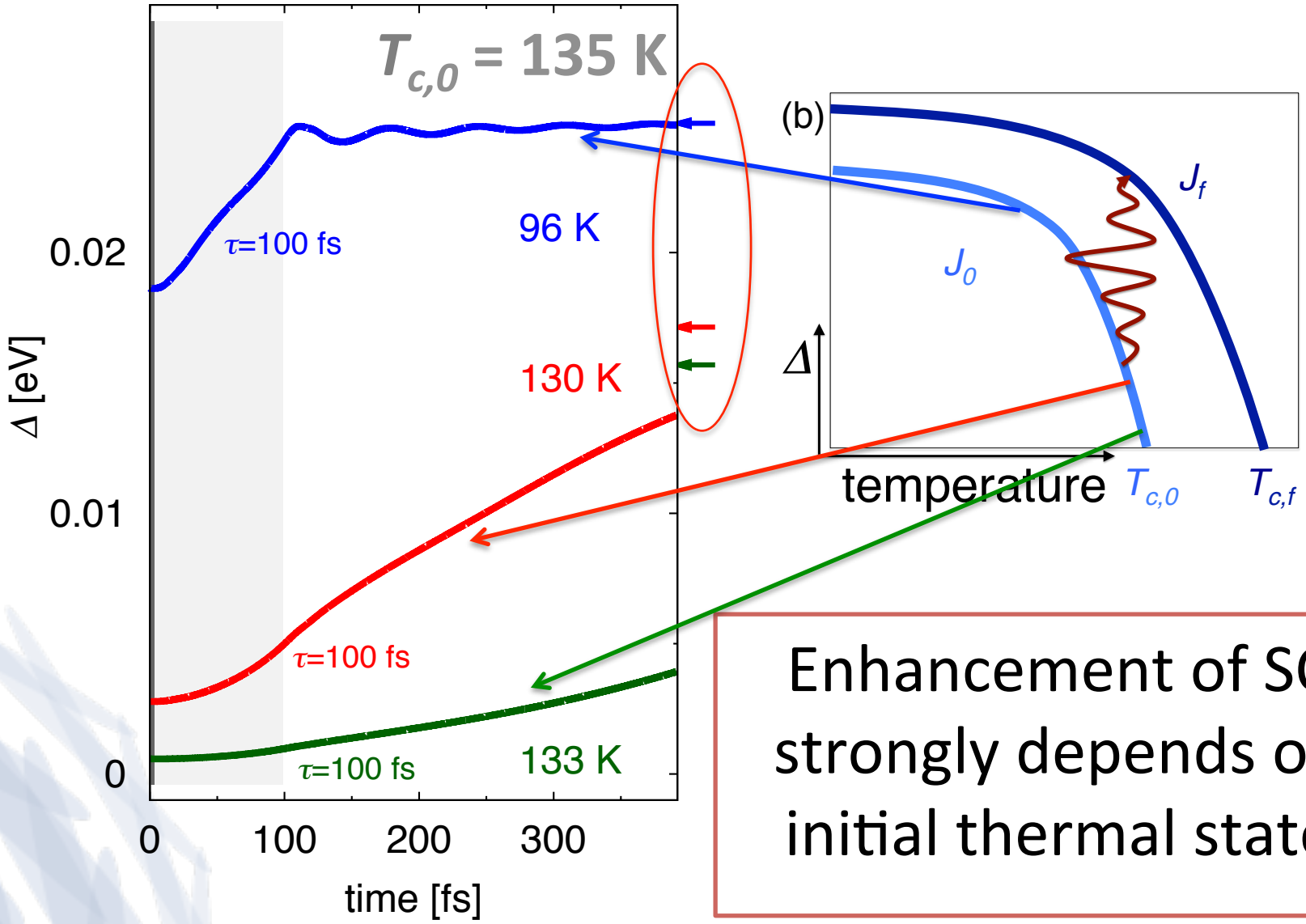
Hopping ramp





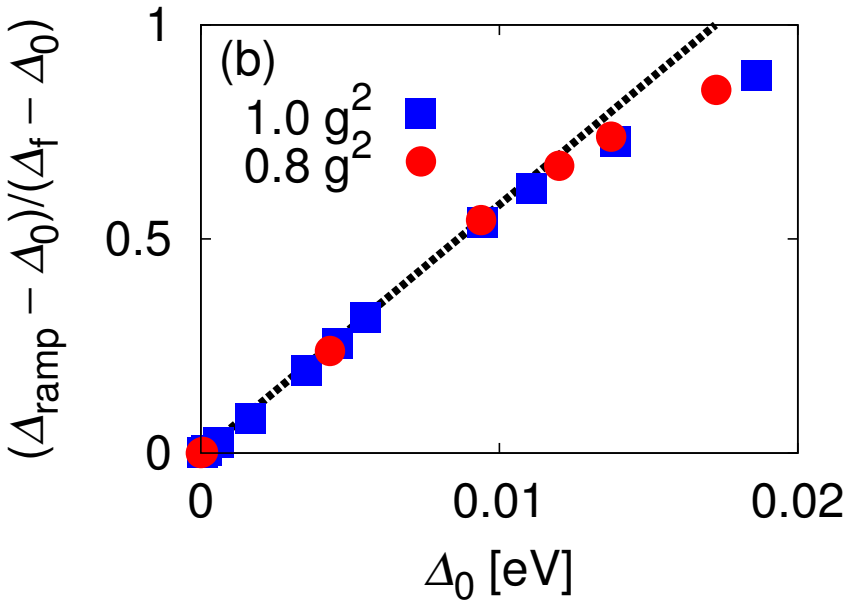
Enhancement of SC via enhanced DOS at Fermi energy?

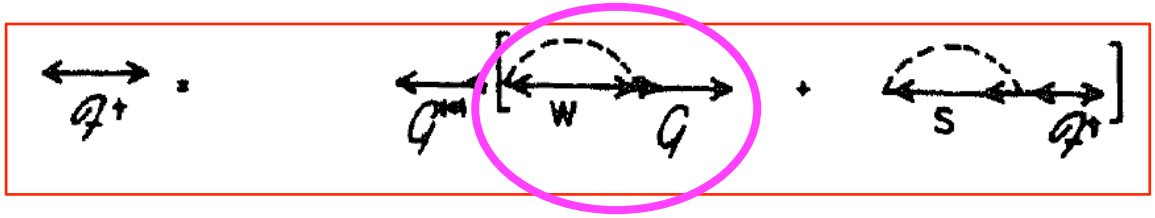
Superconductor evolution



Enhancement of SC strongly depends on initial thermal state

Enhancement during ramp

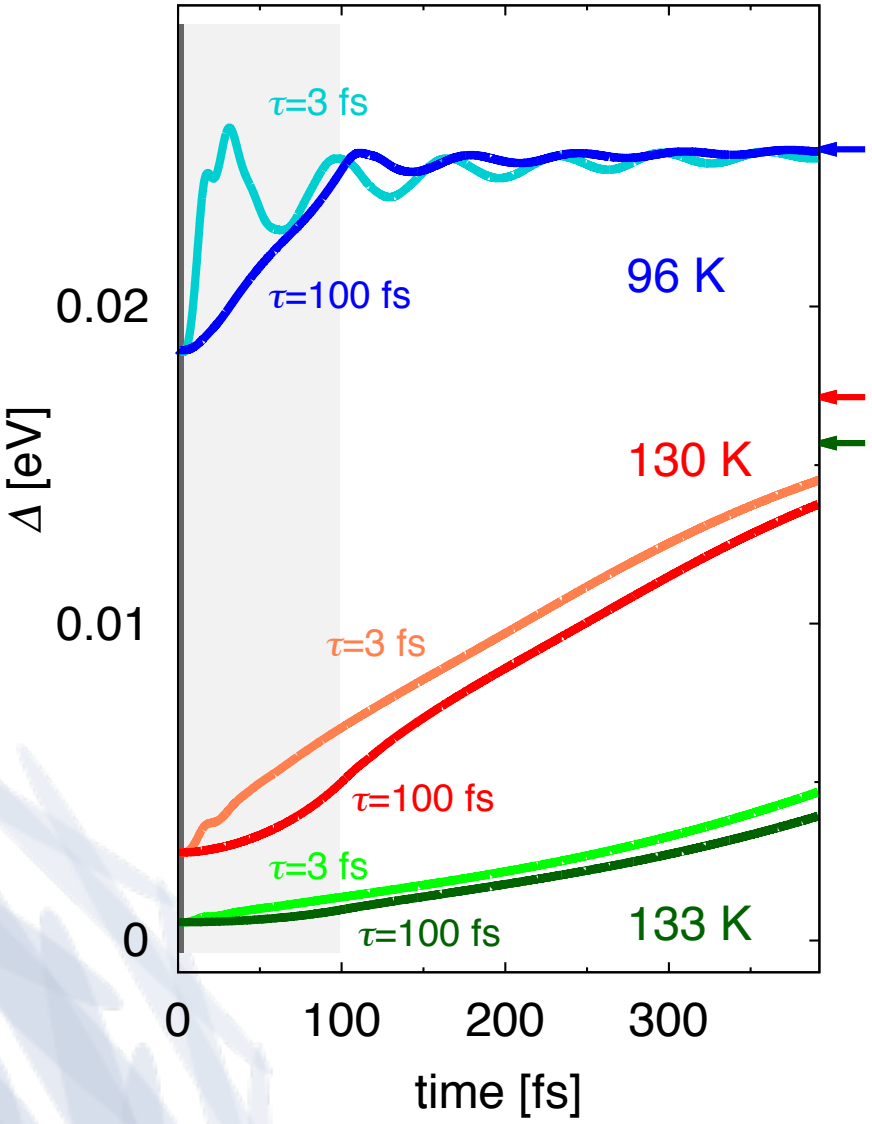




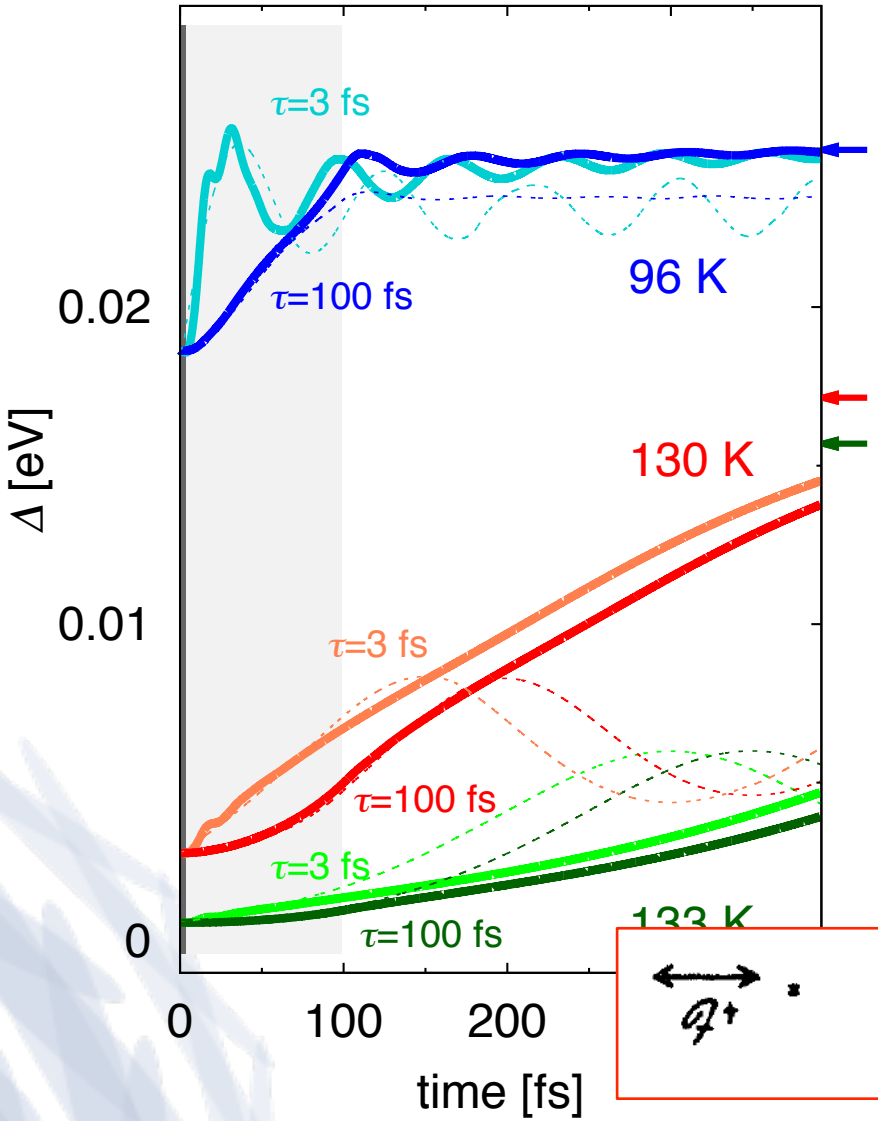
Order parameter enhancement ~Δ_0

determines time scale on which SC can be induced by quasistatic modification of effective pairing strength!

Superconductor evolution



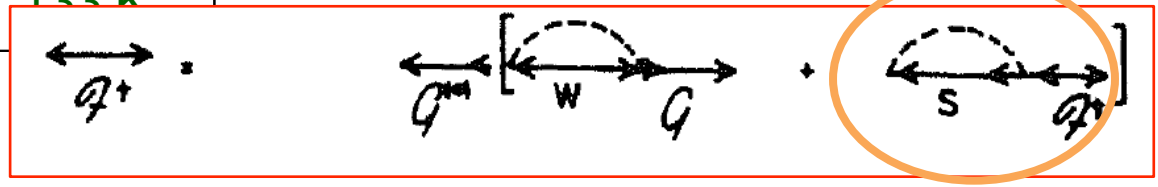
Superconductor evolution



dashed: no dissipation (BCS only)

Dissipation of energy to phonons helps SC enhancement for fast ramps

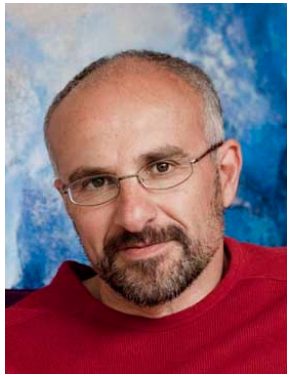
Dissipation important for approach to final thermal state



Summary *arXiv:1505.07575*

- Light-enhanced superconductivity via nonlinear phononics: order parameter versus dissipative dynamics

A. F. Kemper



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