# HELIUM-LIKE DONORS IN SILICON FOR STIMULATED RAMAN SCATTERING

R.Kh. Zhukavin, V.V. Tsyplenkov, V.N. Shastin

Institute for Physics of Microstructures

N.Novgorod, Russia

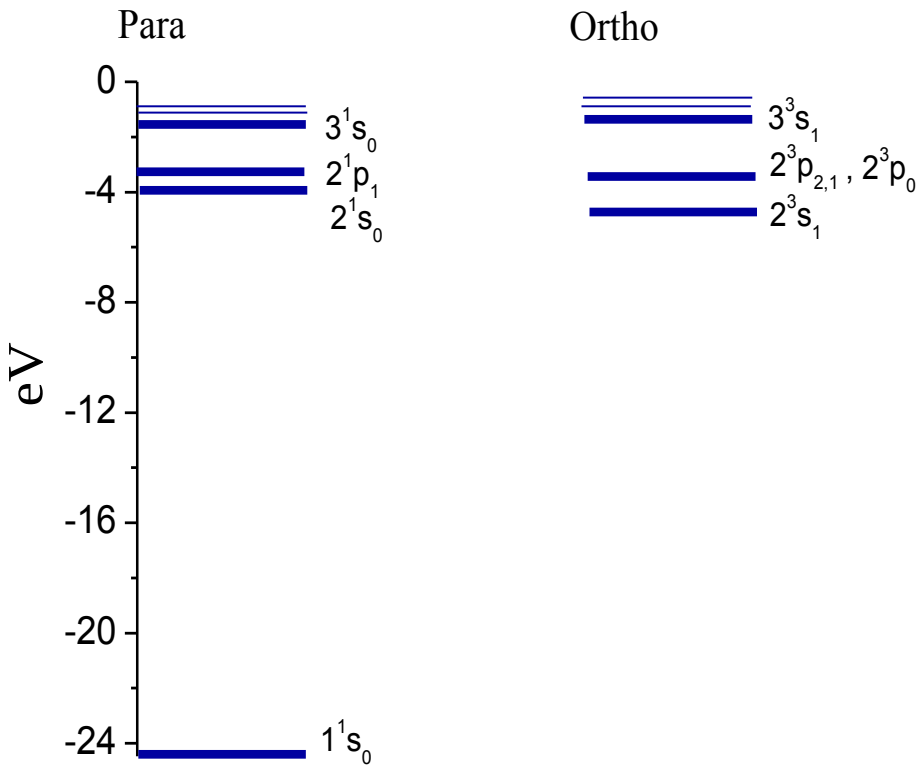
## Helium atom

***Para states***
***(spin singlets)***

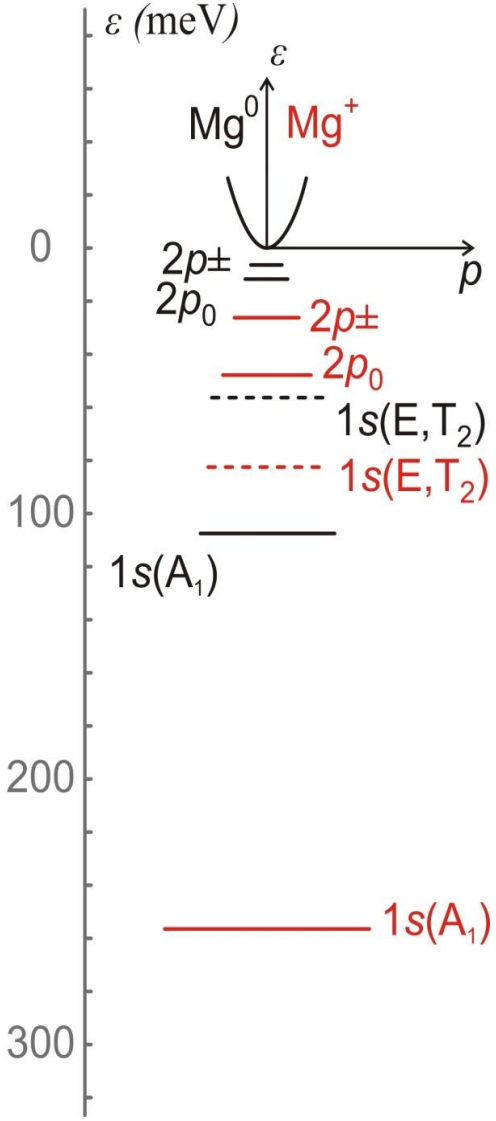
$$\Psi(r_1, r_2) = \Psi(r_2, r_1)$$

***Ortho states***
***(spin triplets)***

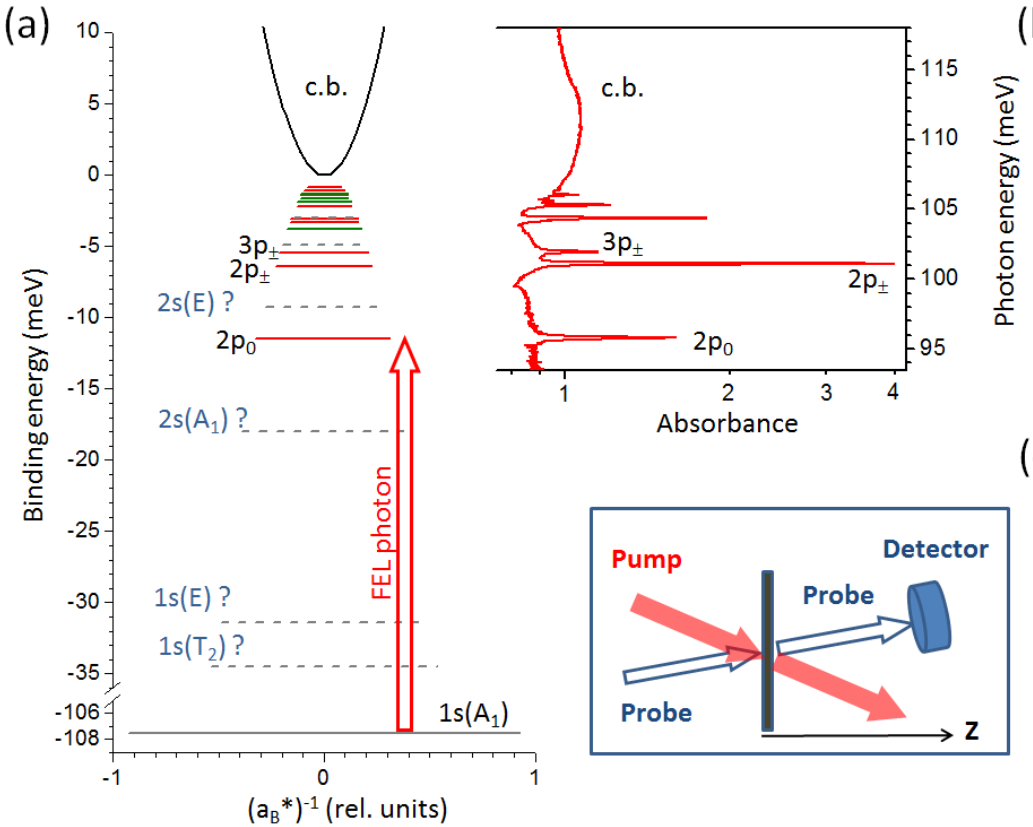
$$\Psi(r_1, r_2) = -\Psi(r_2, r_1)$$




## Mg in silicon



# Pump-probe measurements for Si:Mg

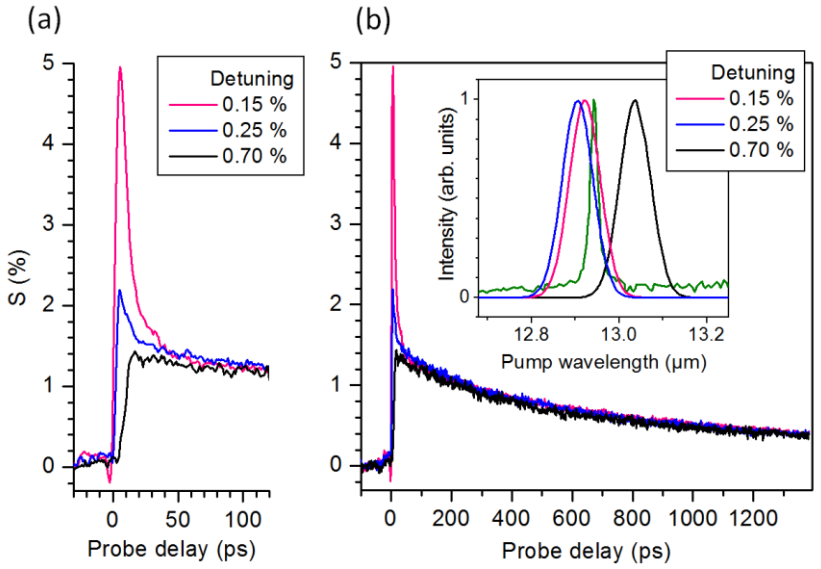






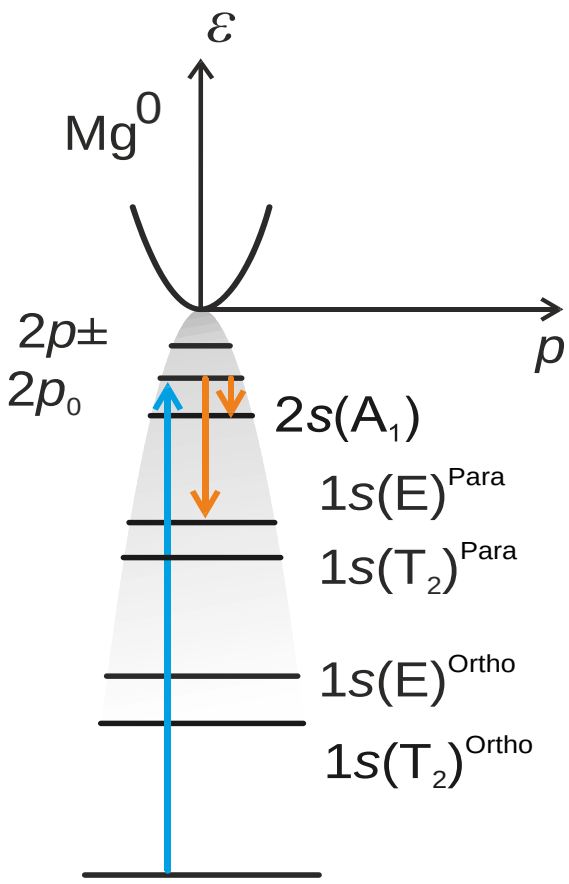
(b)

**Short lifetime for $2p_0$ and $2p_{\pm}$!**

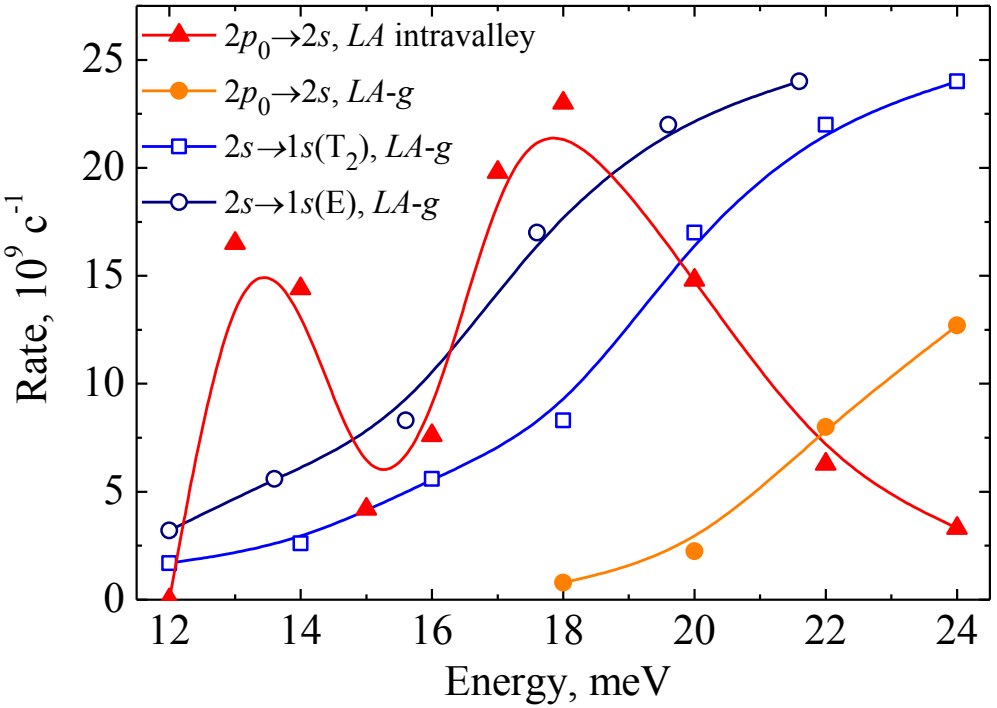



(c)

The lower relaxation of ortho states can influence on gain under the photoionization




The role of two-phonon relaxation should be investigated
since one-phonon steps hardly explain short lifetimes



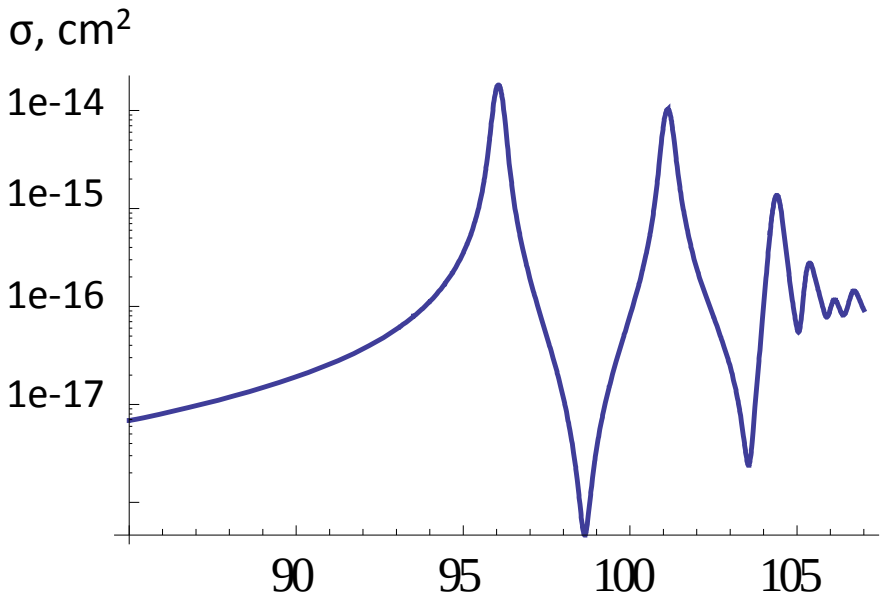

1s(A1)

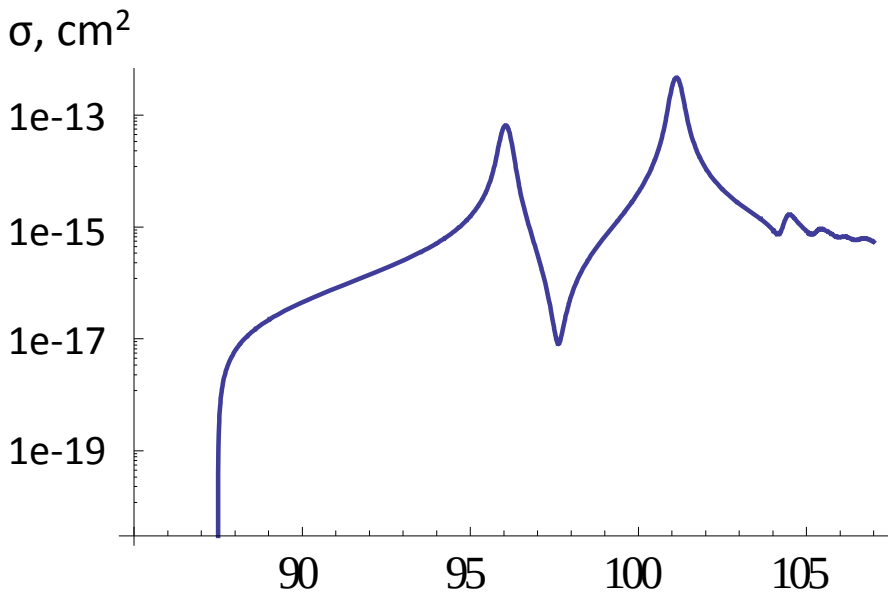
resonant pumping – reduces amount of free electrons and ortho states, less sensitive to lifetimes and broadening

Raman cross-section for 1s(A1)-1s(E)

Raman cross-section for 1s(A1)-2s(E)

Pump flux density – $10^{25}$ photon/(cm$^2$ s)



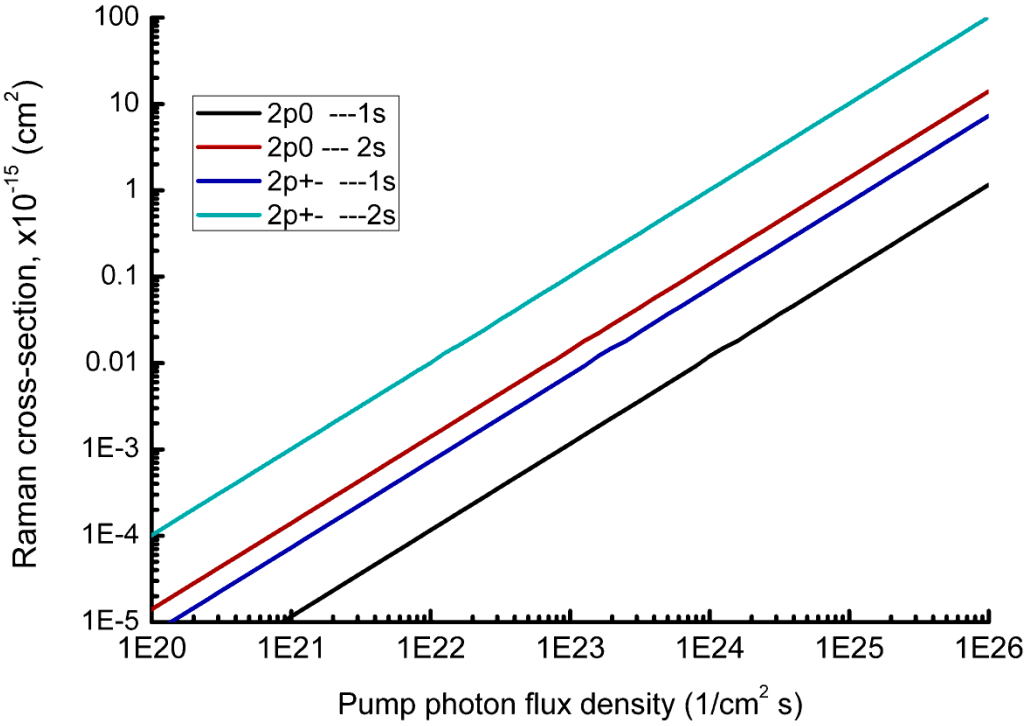

Pump Photon energy, meV

$$\sigma_\delta = 4\pi^2 \left| \sum_n \frac{d_{2n}'^{*} d_{n1}}{\omega_{n1} + i\delta_n + \delta - \omega} + \frac{d_{2n} d_{n1}'^{*}}{\omega_{n1} + i(\delta_n - \delta') + \delta + \omega'} \right|^2 \frac{\omega'}{c\hbar^3} \frac{J_\omega}{\Gamma}$$

$$\sigma = \frac{1}{\sqrt{2\pi}\Delta} \int \sigma_\delta e^{-\frac{\delta^2}{2\Delta^2}} d\delta$$

Distribution of ground state energy

# Raman cross-section under resonant pumping onto $2p_0$ and $2p_{\pm}$




$$\sigma_R=\left(\frac{4\pi\alpha}{n}\right)\frac{\hbar\omega_{out}}{\Gamma}\,|\langle n|x|i\rangle|^2|\langle n|x|i\rangle|^2\,\frac{\hbar}{(\delta^2+\Gamma^2)}\times Ipump$$

$|\langle n|x|i\rangle|$, $|\langle n|x|i\rangle|$ - matrix elements, for resonant case $\delta = 0$, $i \Longrightarrow \psi_{2p}$

α=1/137, n – refractive index, Γ – linewidth, $I_{pump}$ – pump intensity,

$\omega_{out} - output\ frequency$,

Khurgin, J. B., Sun, G., Friedman, L. R., Soref, R. A. (1995).
*Journal of Applied Physics*, ***78***(12), 7398-7400.