

Limitation of single-laser repumping schemes for laser cooling of Sr atoms

Naohiro Okamoto, Takatoshi Aoki, and Yoshio Torii

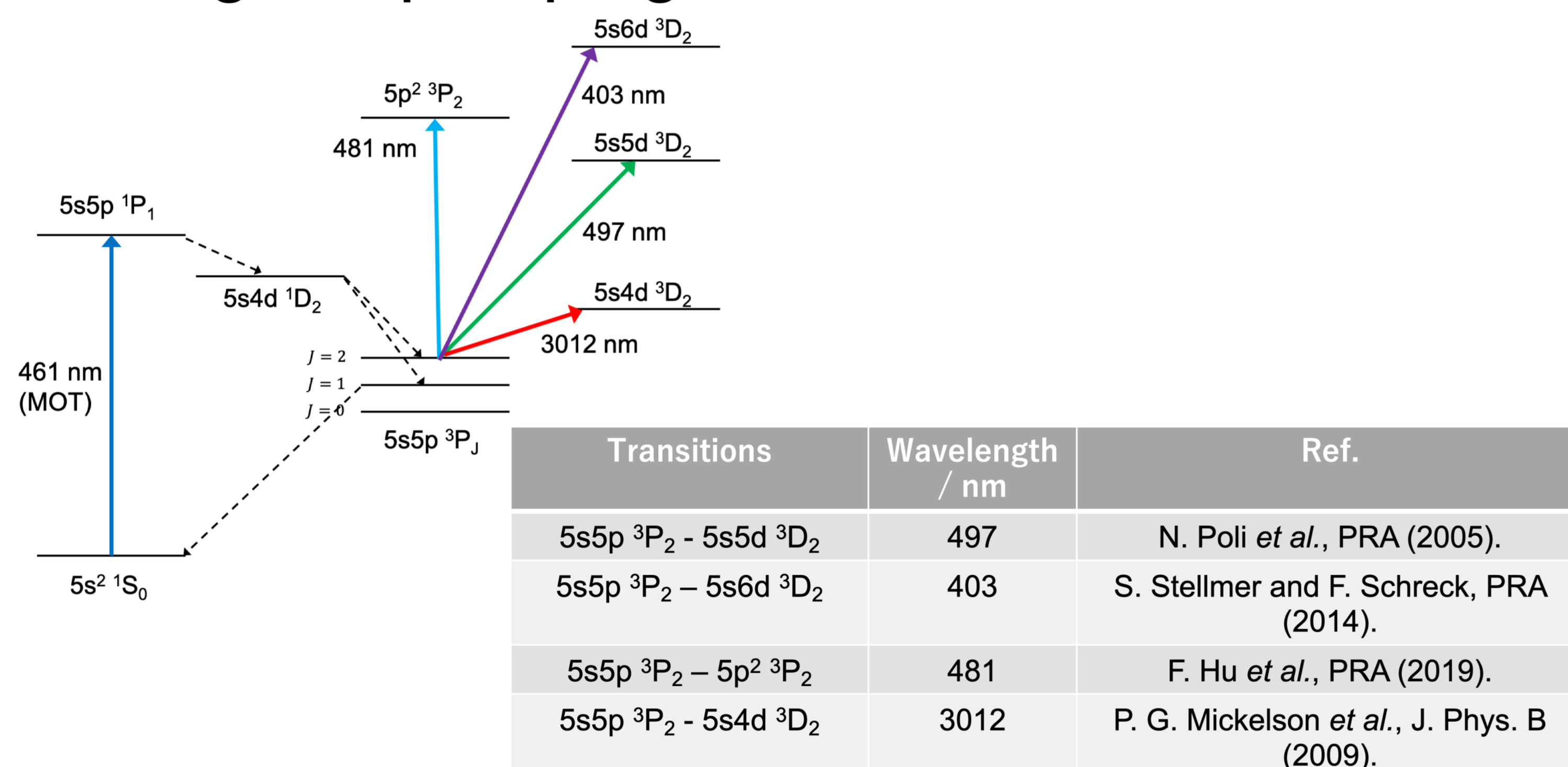
Graduate School of Arts and Sciences, The University of Tokyo, Tokyo 153-8902, Japan

Abstract

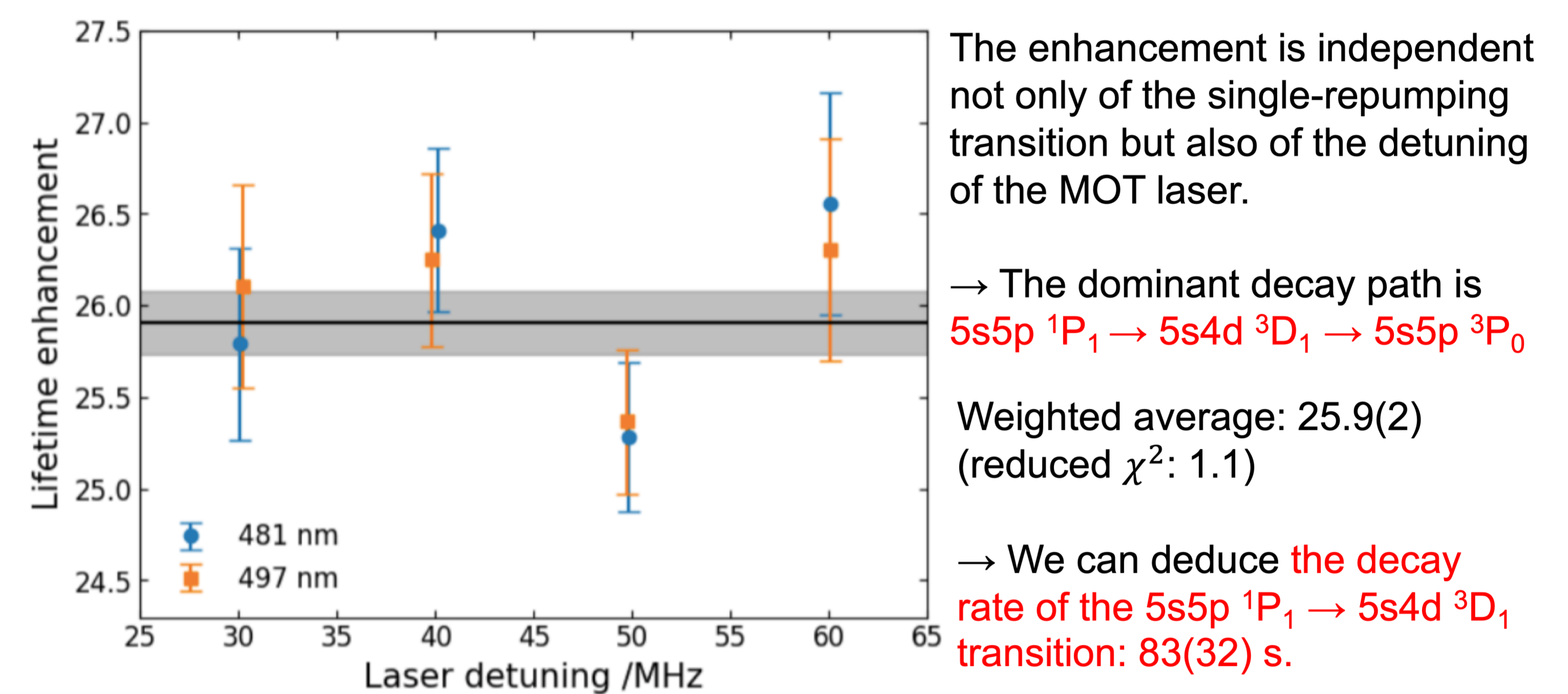
We investigate the performance of a magneto-optical trap (MOT) of Sr atoms for two single-repumping schemes: $5s5p\ ^3P_2 - 5p^2\ ^3P_2$ (481 nm) and $5s5p\ ^3P_2 - 5s5d\ ^3D_2$ (497 nm), revealing that the dominant decay path from the $5s5p\ ^1P_1$ state to the $5s5p\ ^3P_0$ state is via the $5s4d\ ^3D_1$ state, not via the upper states accessed by the single-repumping lasers. Due to this decay path, the enhancement in the lifetime of the MOT is limited to 25.9(2) for any single-repumping schemes. For the first time, we determined that the branching ratio of the $5s5p\ ^1P_1 \rightarrow 5s4d\ ^3D_1 \rightarrow 5s5p\ ^3P_0$ decay path is $1:3.9 \times 10^6$ and the decay rate from the $5s5p\ ^1P_1$ state to the $5s4d\ ^3D_1$ state is $83(32)\text{ s}^{-1}$. This result shows the atom number in the MOT is significantly limited for a single-repumping scheme when a long loading time ($\geq 1\text{ s}$) is required. This finding will contribute to the construction of field-deployable optical lattice clocks.

(This is provisional version, so it will be amended after June 1st.)

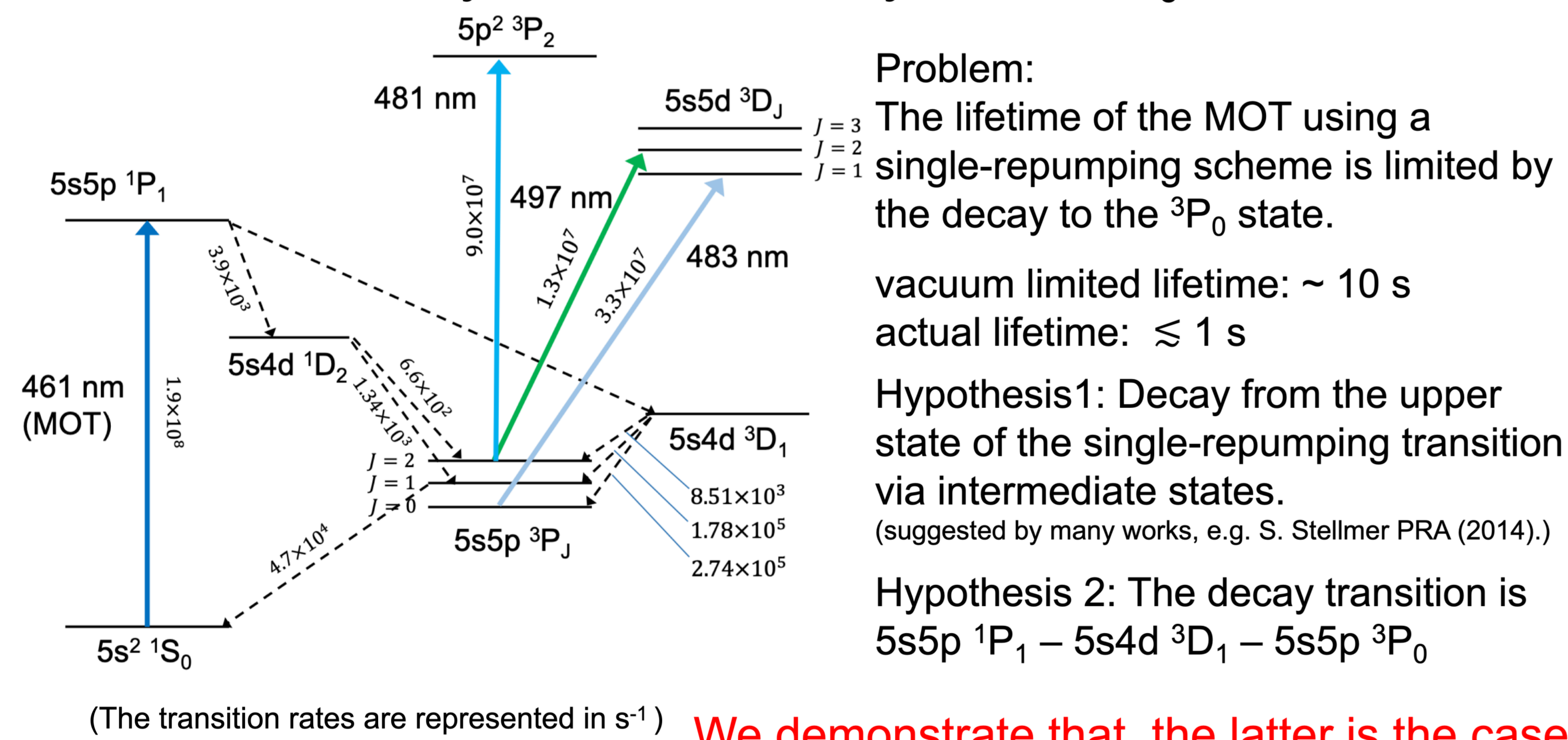
Single-repumping scheme



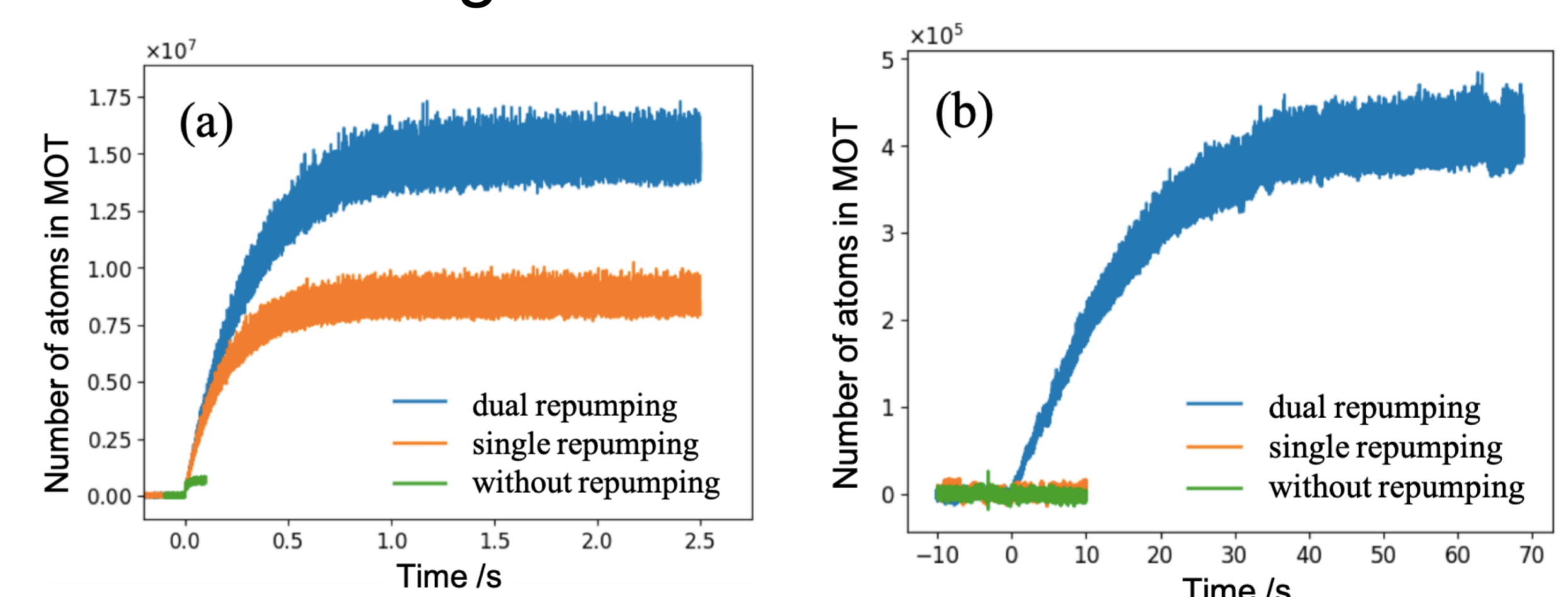
Lifetime enhancement for single repumping schemes



Motivation: why does the decay to the 3P_0 state occur?

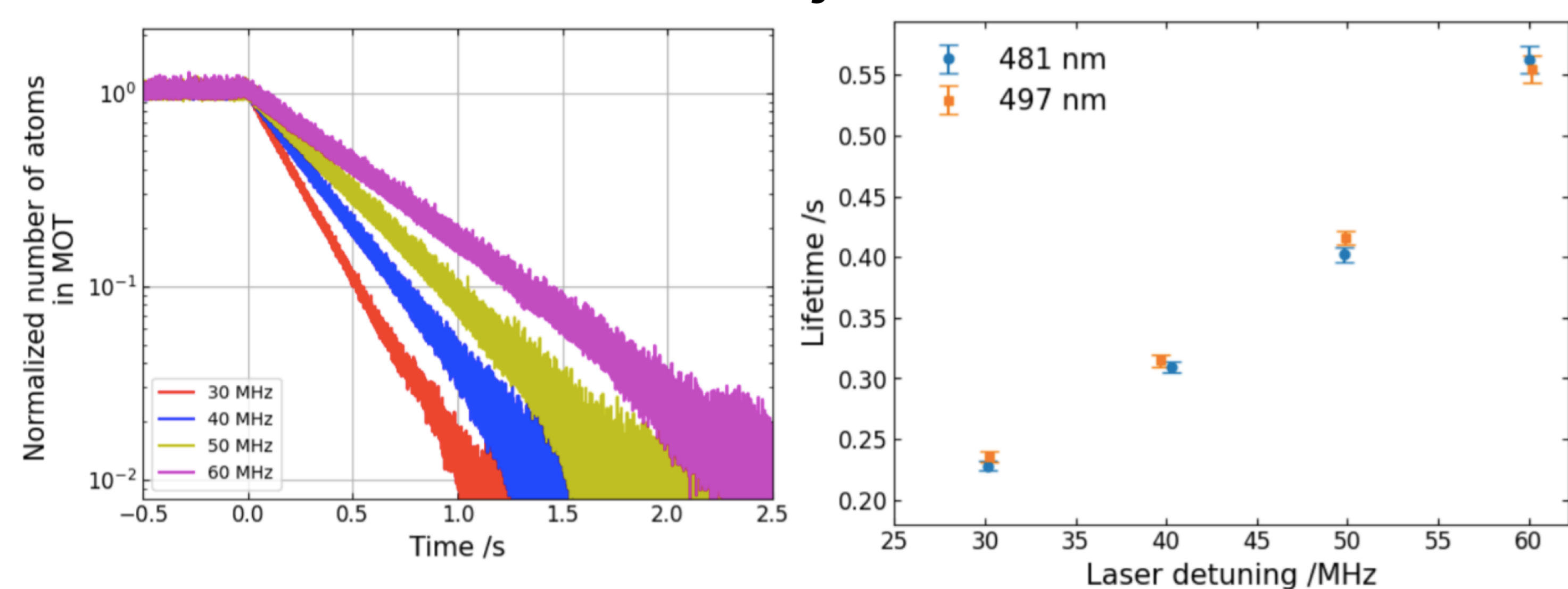


Limitation of single-laser repumping schemes for laser cooling of Sr atoms



When long loading rate ($\geq 1\text{ s}$) is needed, it is required to use not only 3P_2 repumping laser, including single-repumping laser, but also 3P_0 repumping laser.

Lifetime comparison between the case of 481 nm and 497 nm injection



Conclusion

- We compared the performance of a MOT of ^{88}Sr atoms for two single-repumping schemes (481 nm and 497 nm), which was independent not only of the single-repumping transition but also of the detuning of the MOT laser.
- This result indicates that the dominant decay path is $5s5p\ ^1P_1 \rightarrow 5s4d\ ^3D_1 \rightarrow 5s5p\ ^3P_0$, which is overlooked so far.
- We determined that the decay rate of the $5s5p\ ^1P_1 - 5s4d\ ^3D_1$ transition is $83(32)\text{ s}^{-1}$.
- Due to this decay path, the atom number in the MOT should be significantly limited for a single-repumping scheme when a long loading time ($\geq 1\text{ s}$) is required.
- Our finding encourages reconsideration of the single-laser repumping schemes for Sr laser cooling.