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Generating LG modes for atom trapping in a Sr optical lattice clock

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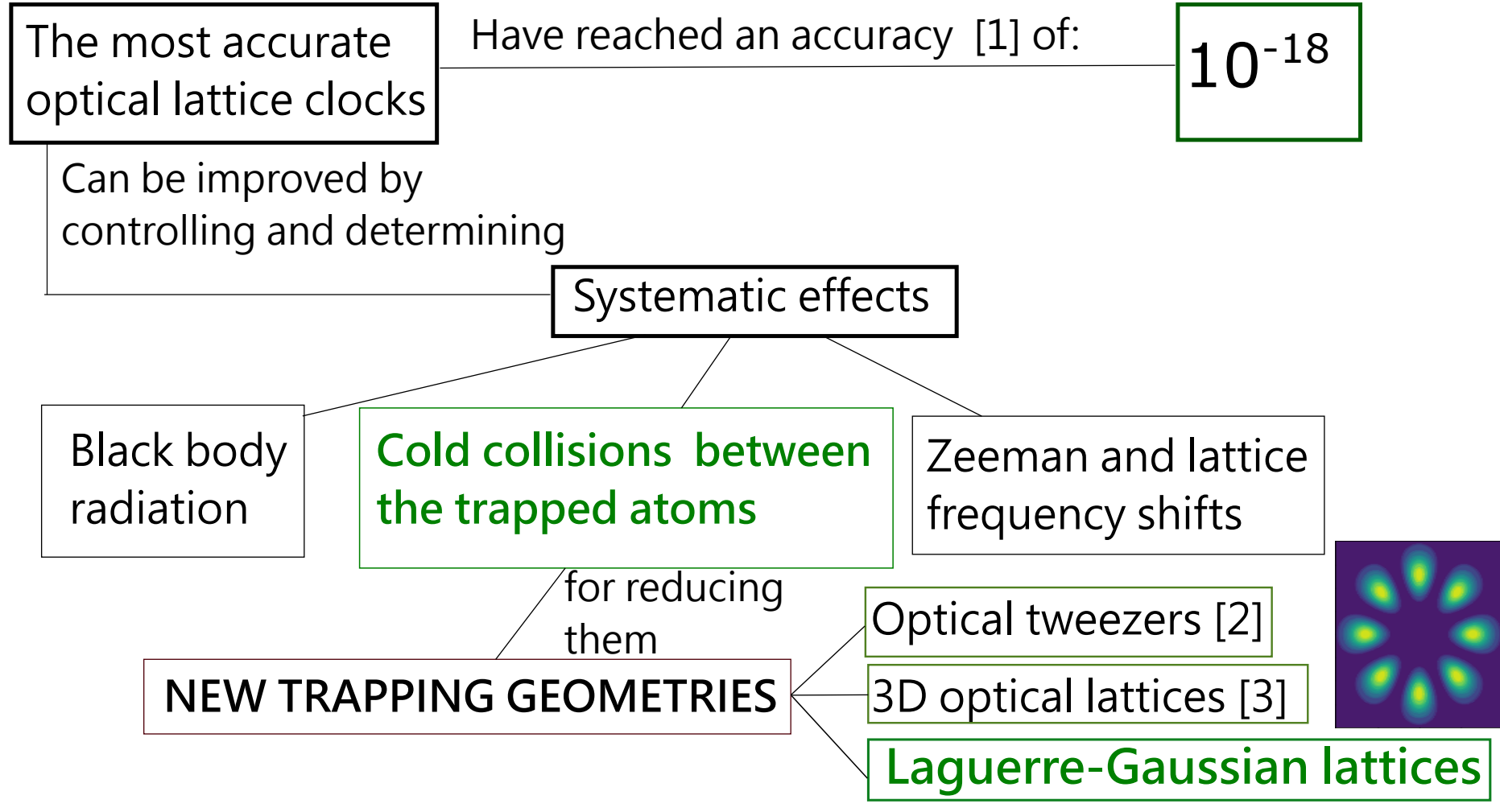
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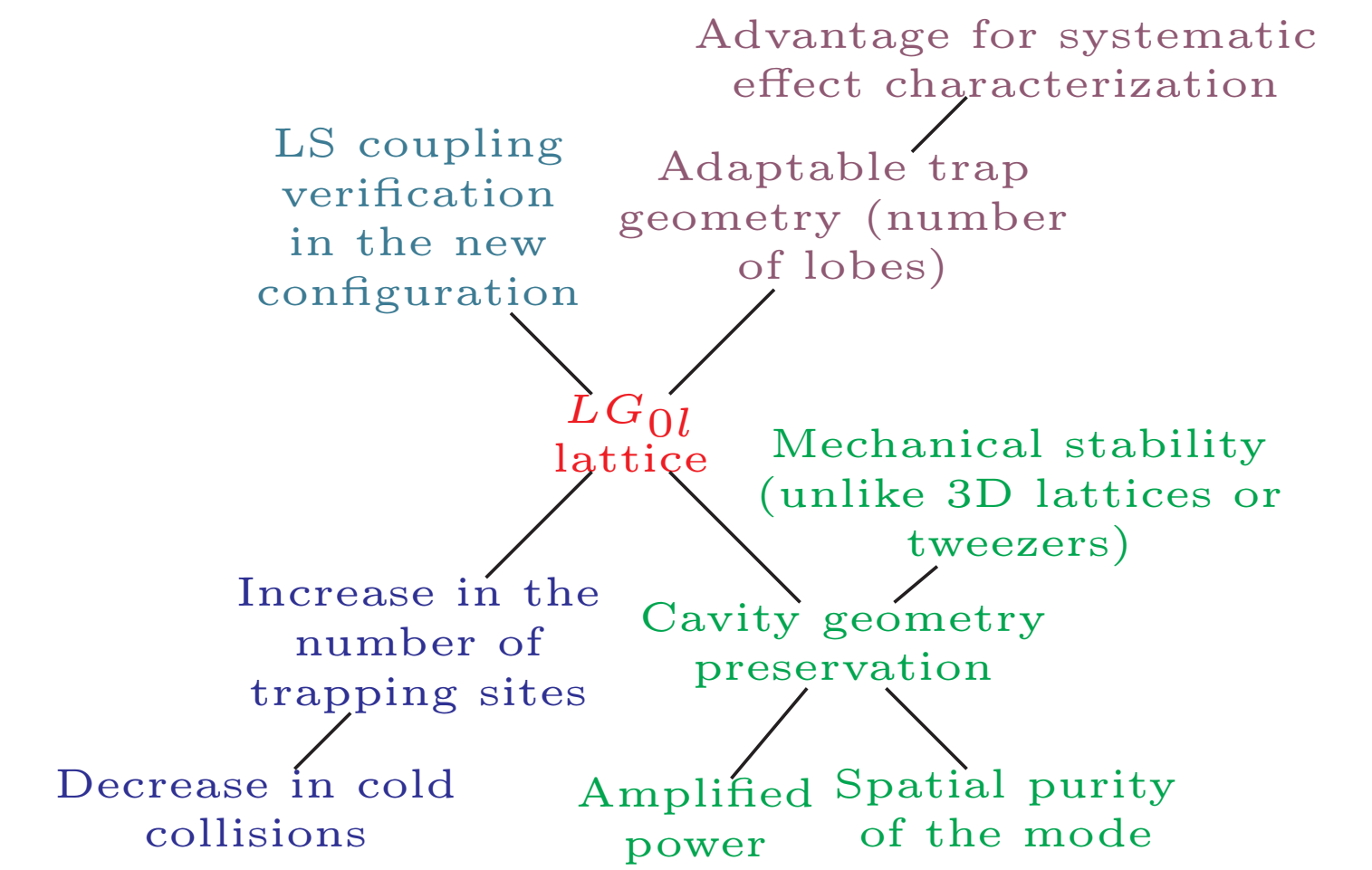
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Introduction



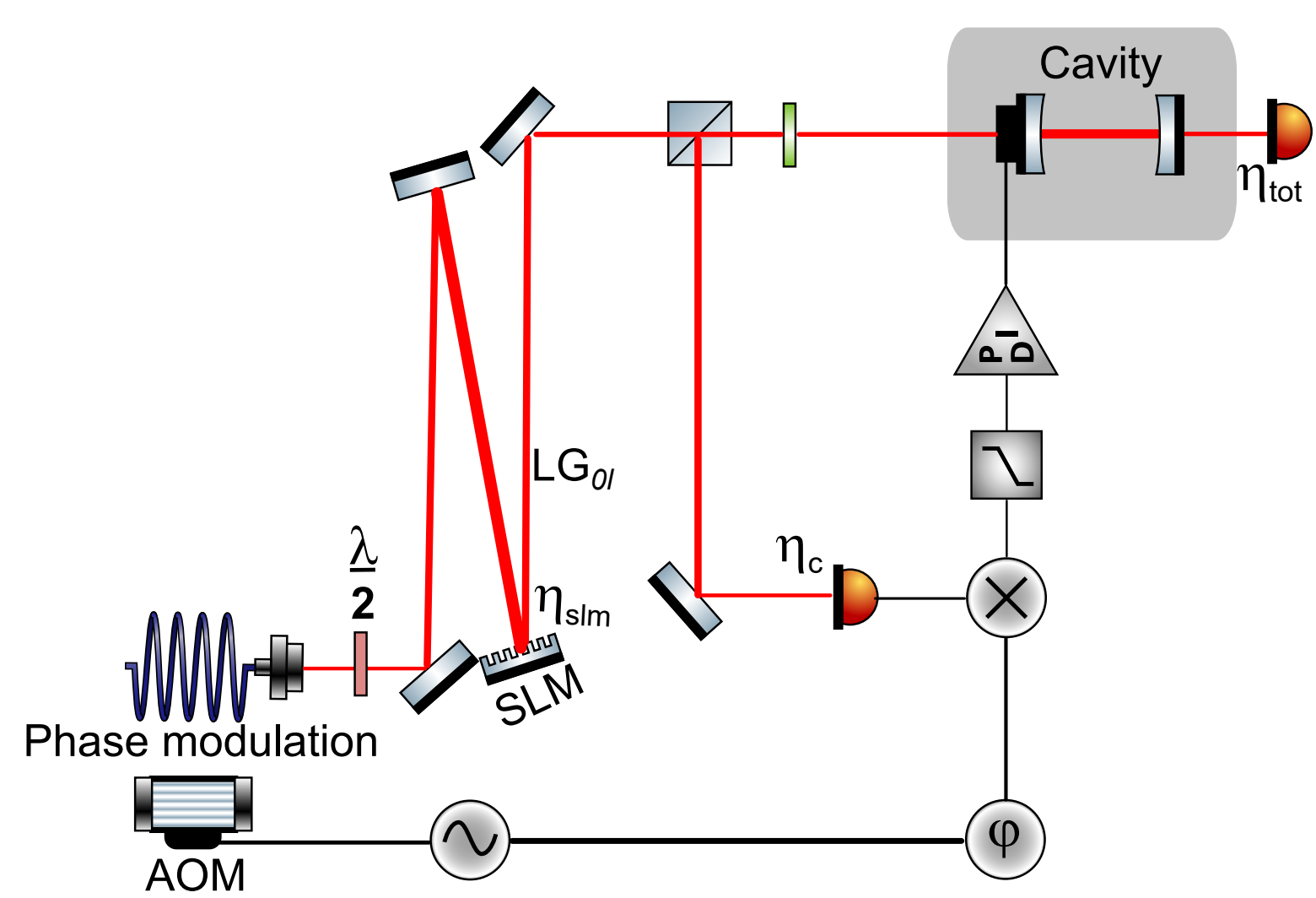
We propose to increase the number of trapping sites in a magic wavelength optical lattice by using sinusoidal LG_{0l} modes with azimuthal index l , whose transverse profile is composed of $2l$ identical trapping sites. Consequently, we expect a better accuracy of our clock by reducing the density of atoms per site. The new proposed trapping potential can be modeled by the equation:

$$U_{0l}(r, \varphi, z) = -\alpha E_1 I_0 e^{-\frac{2r^2}{w^2(z)}} \cos^2[kz - \psi_l(z)] \times \left(\frac{-2r^2}{w^2(z)}\right)^{|l|} \cos^2(l\varphi)$$



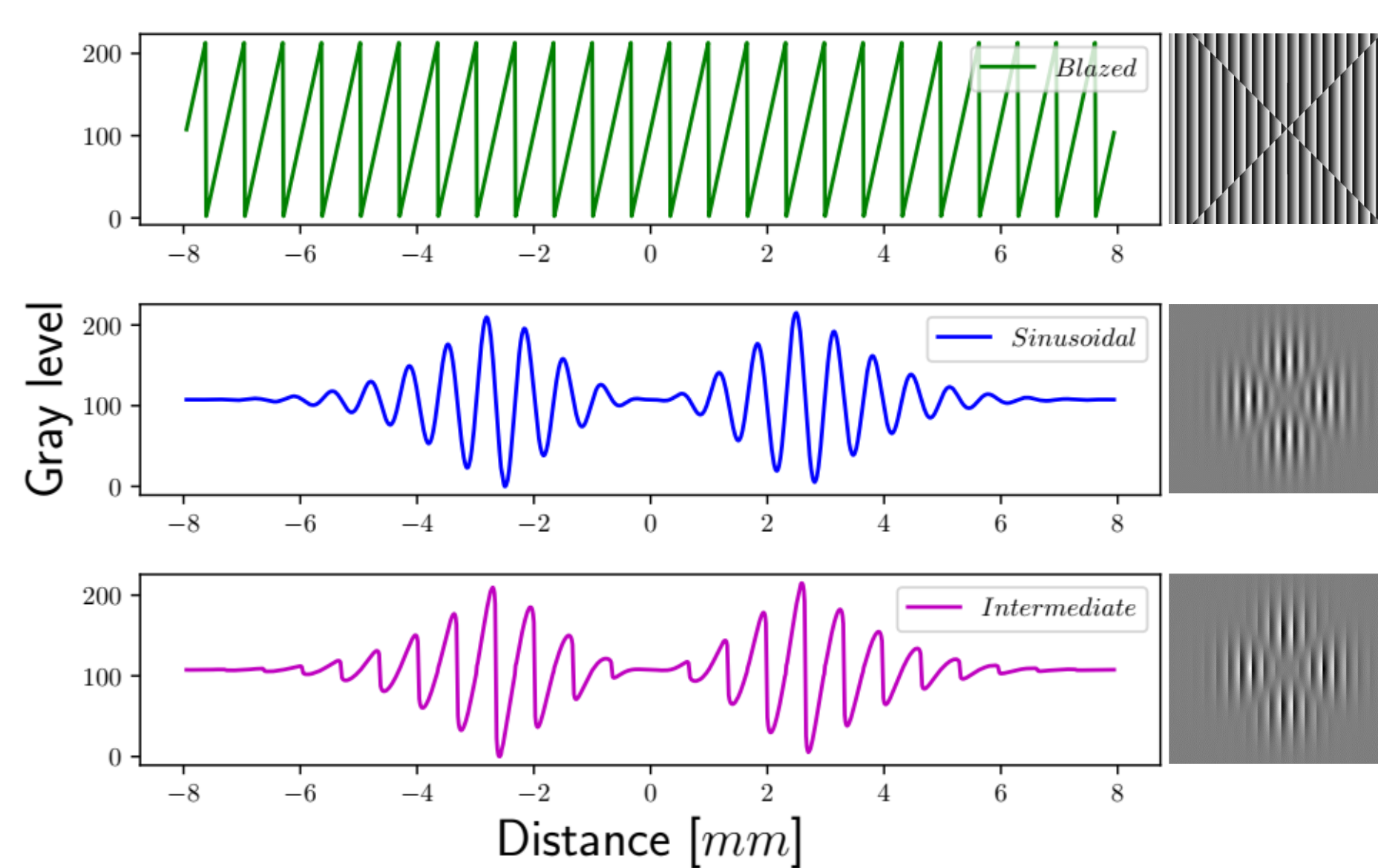
I. LG modes implementation

⇒ **Setup** for the generation and PDH locking of LG modes.

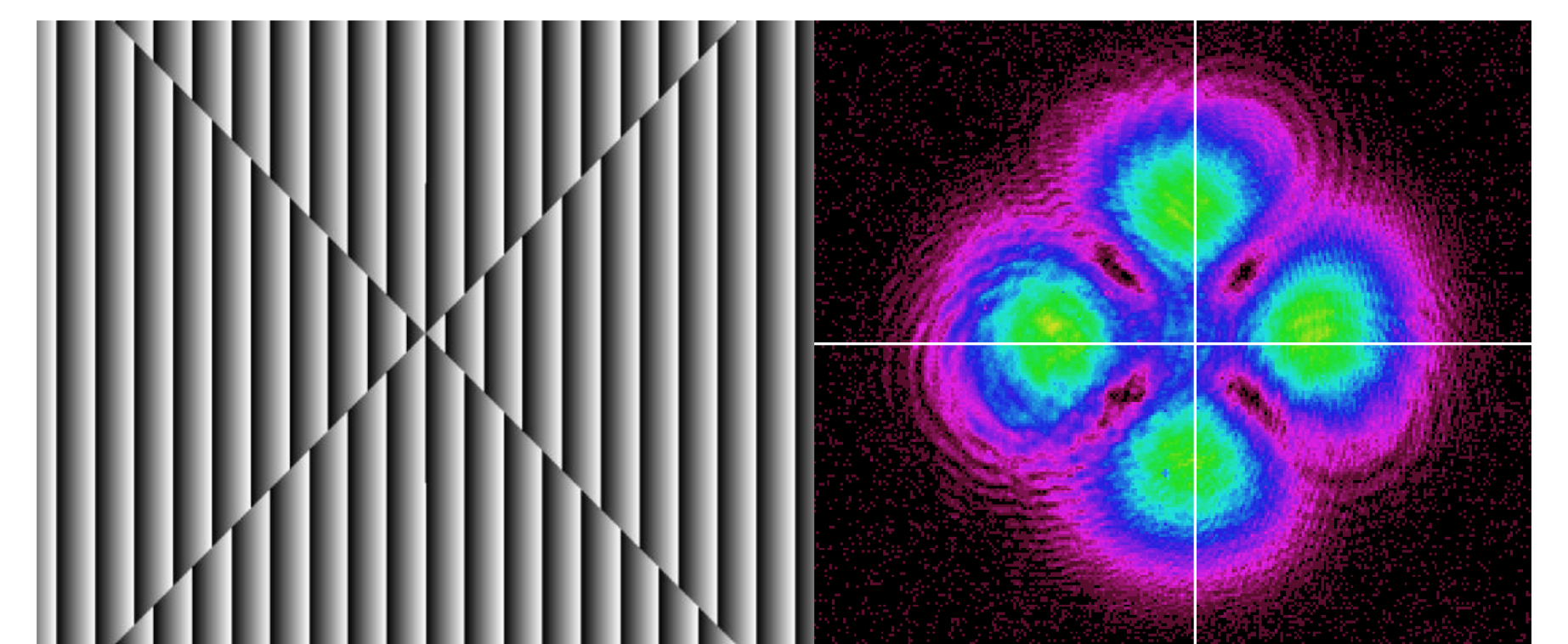


The LG modes are generated using an LCOS-SLM. The SLM displays a computer generated hologram which encode the phase of the LG mode [4] and a diffraction

grating. The shape of the desired mode appears in the first diffraction order.

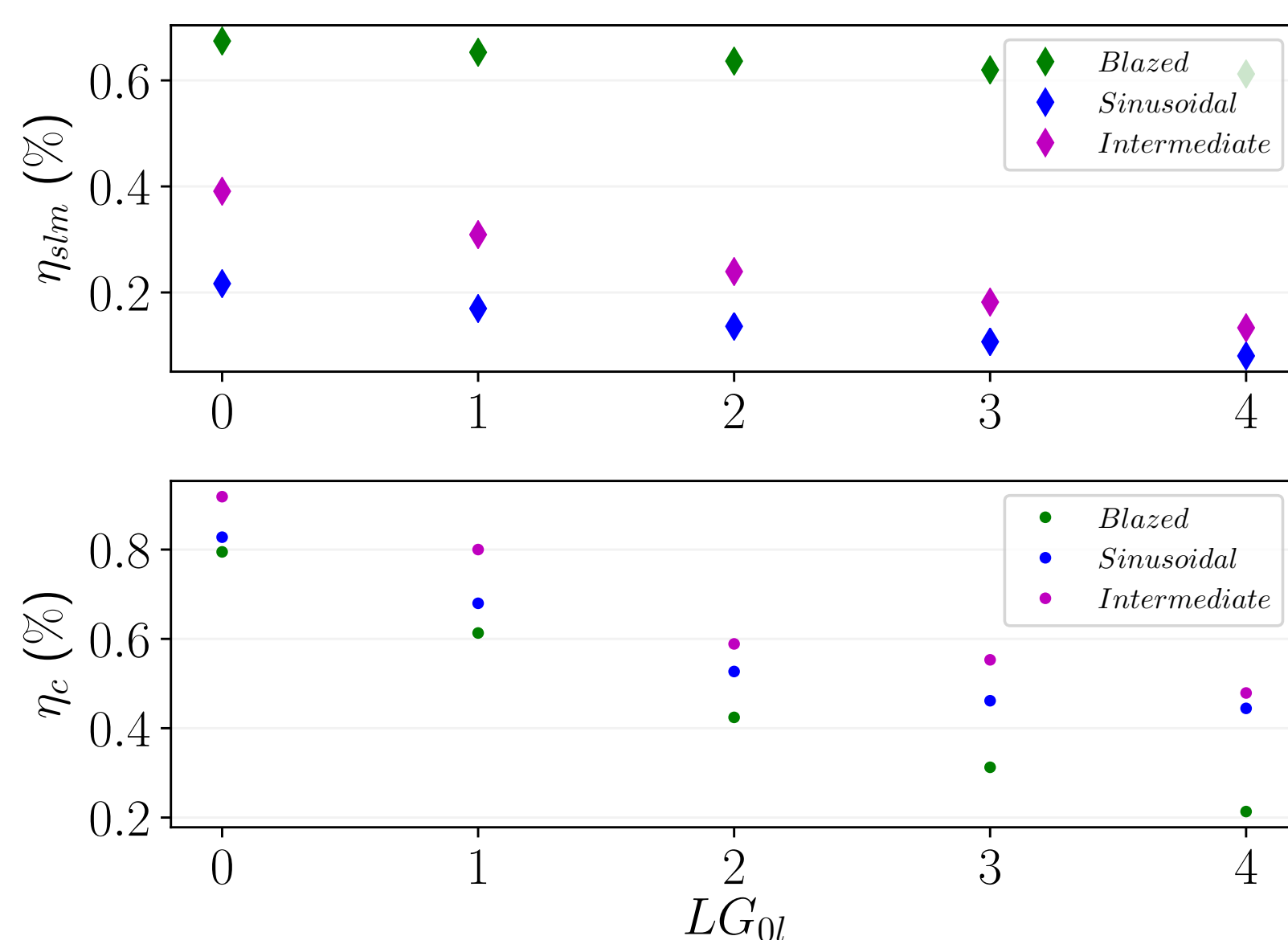


⇒ **Hologram and generated LG_{02} mode**



The cavity filters the shape of the beam diffracted by the SLM when using a blazed grating. The hologram corresponds to a spatial period $T_x = 662.5 \mu\text{m}$ or a number of grooves $n_x = 24$.

II. SLM diffraction and coupling efficiencies



⇒ **The SLM diffraction efficiency η_{slm}** , can be improved by decreasing the number of grooves. The results on the left figure were obtained for $n_x = 70$.

⇒ **Blazed grating** presents $\eta_{slm}^B \sim 70\%$ on the first diffraction order. In spite of some similarities the diffracted order exposes a shape other than the LG_{0l} mode.

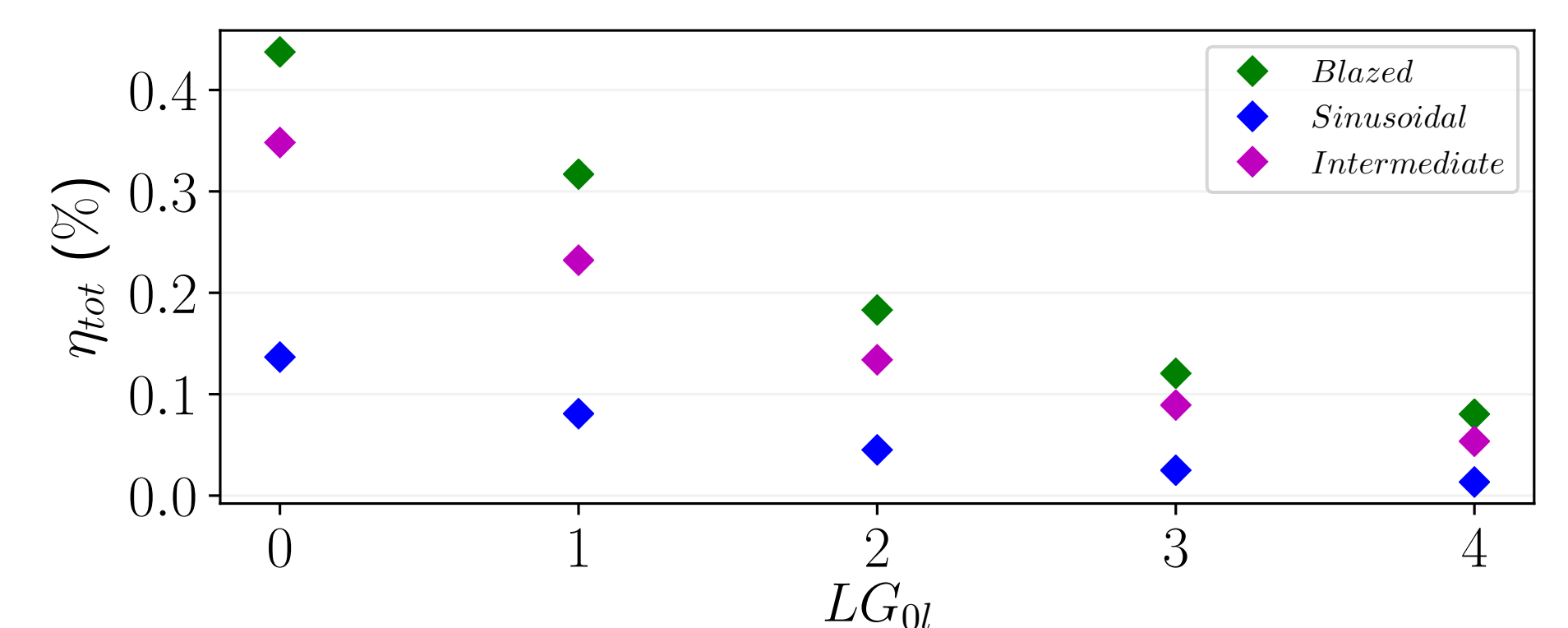
⇒ **Sinusoidal grating** exposes the desired LG_{0l} encoded on the hologram. However, $\eta_{slm}^S < 30\%$.

⇒ **Intermediate grating** shows $\eta_{slm}^I \sim 40\%$. There was two diffraction orders, where one of them was the LG_{0l} mode.

⇒ **Coupling efficiency:** $\eta_c^I > \eta_c^S > \eta_c^B$

III. Total efficiency

The total efficiency of the setup: $\eta_{tot} \approx \eta_{slm}\eta_c$.



⇒ **Blazed grating is the most efficient** for the setup along the optical path, so it remains appropriate for the creation of the optical lattice trap.

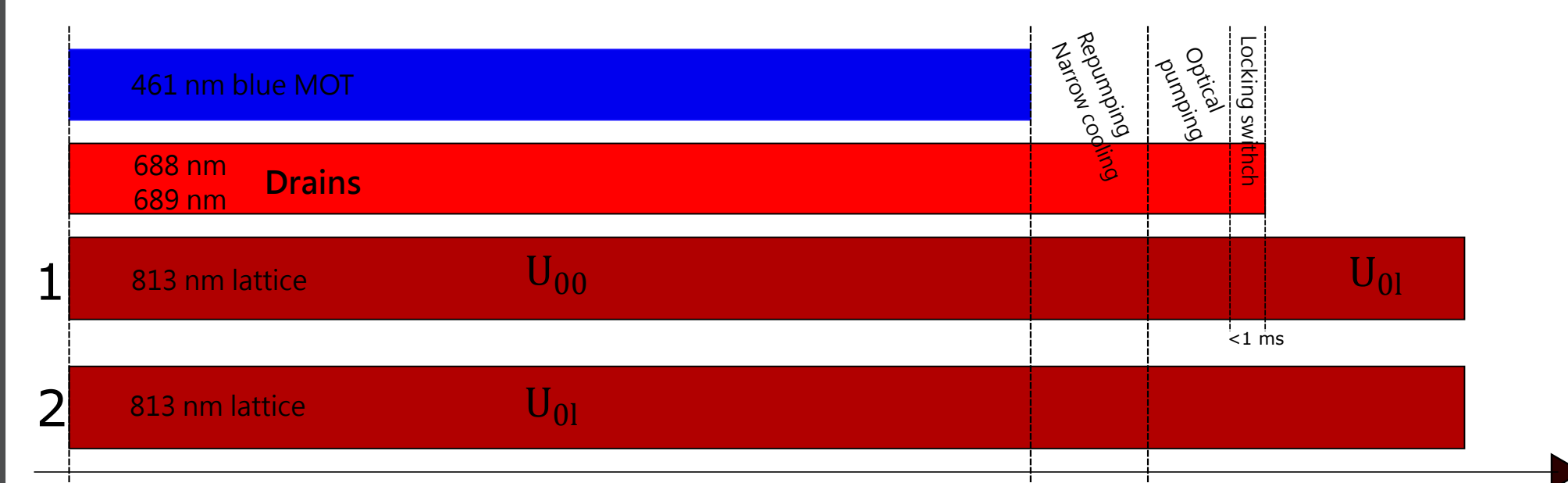
LG_{0l}	0	1	2	3	4
η_{tot}	0.438	0.317	0.183	0.121	0.080
$U_0 [E_r]$	1095	792	457	302	200

On our Sr clocks the minimum depth required is about $100E_r$ for the clock interrogation stage. However, with the optical drain technique we used to transfer the atoms from the blue MOT to the optical lattice [5], a trapping depth as large as $1000E_r$ is required.

IV. LG lattice loading methods

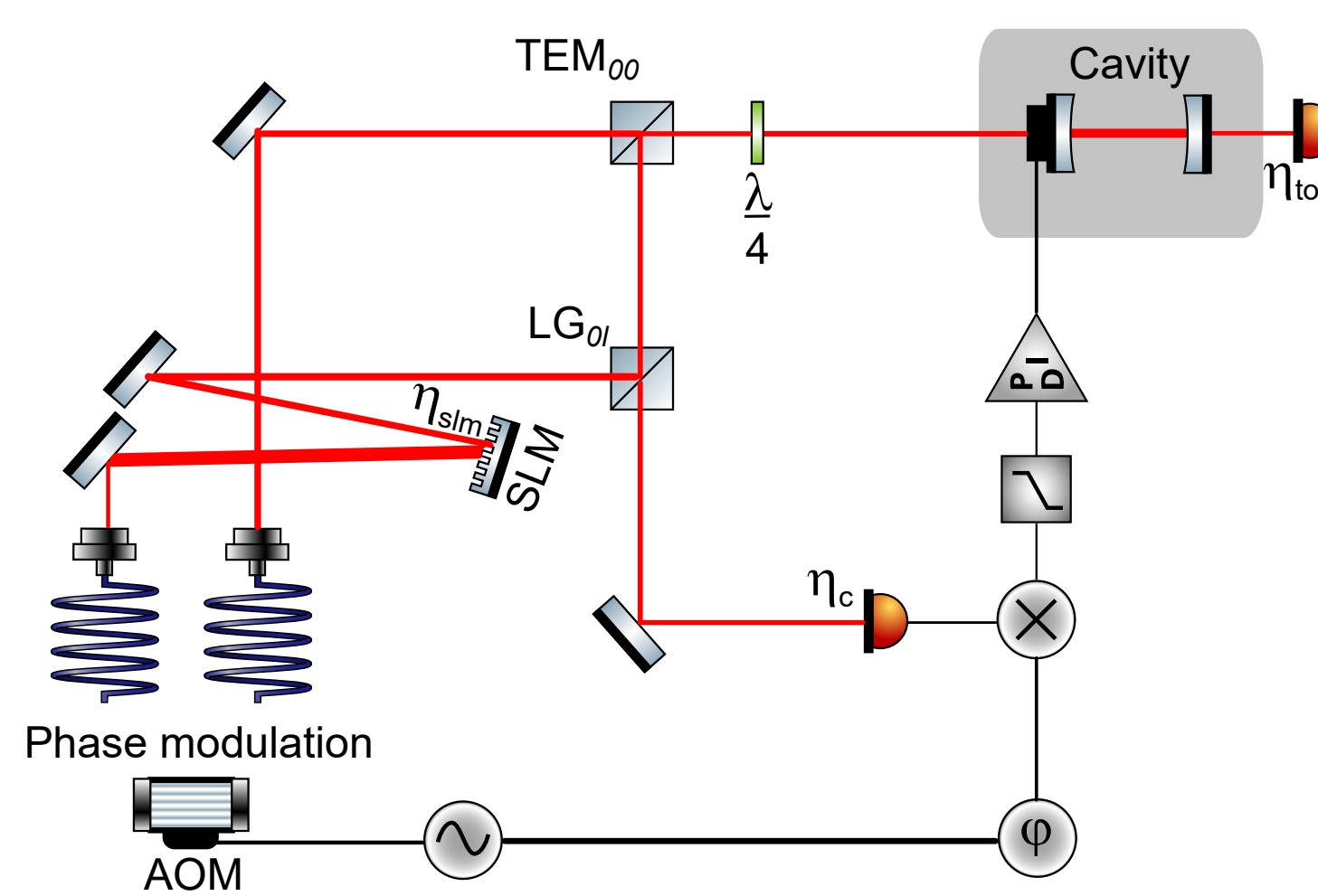
Having generated the LG modes we expect to load the new lattice by two different methods.

LG lattice potential. The challenge is the determination of the best geometry of the drain.



⇒ **Method 1:** Transfer of atoms from a TEM_{00} lattice potential to an LG lattice potential. An automatic locking switch between the selected modes is being developed.

⇒ **Method 2:** Transfer of atoms from the MOT to the



First, we expect to compute the loading efficiencies of the LG lattice by running Montecarlo simulations for the proposed methods, and then we will run experiments for comparing them. Also, future works will focus on studying the systematic uncertainty associated with cold collisions and lattice light shifts effects.

Acknowledgements

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References

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