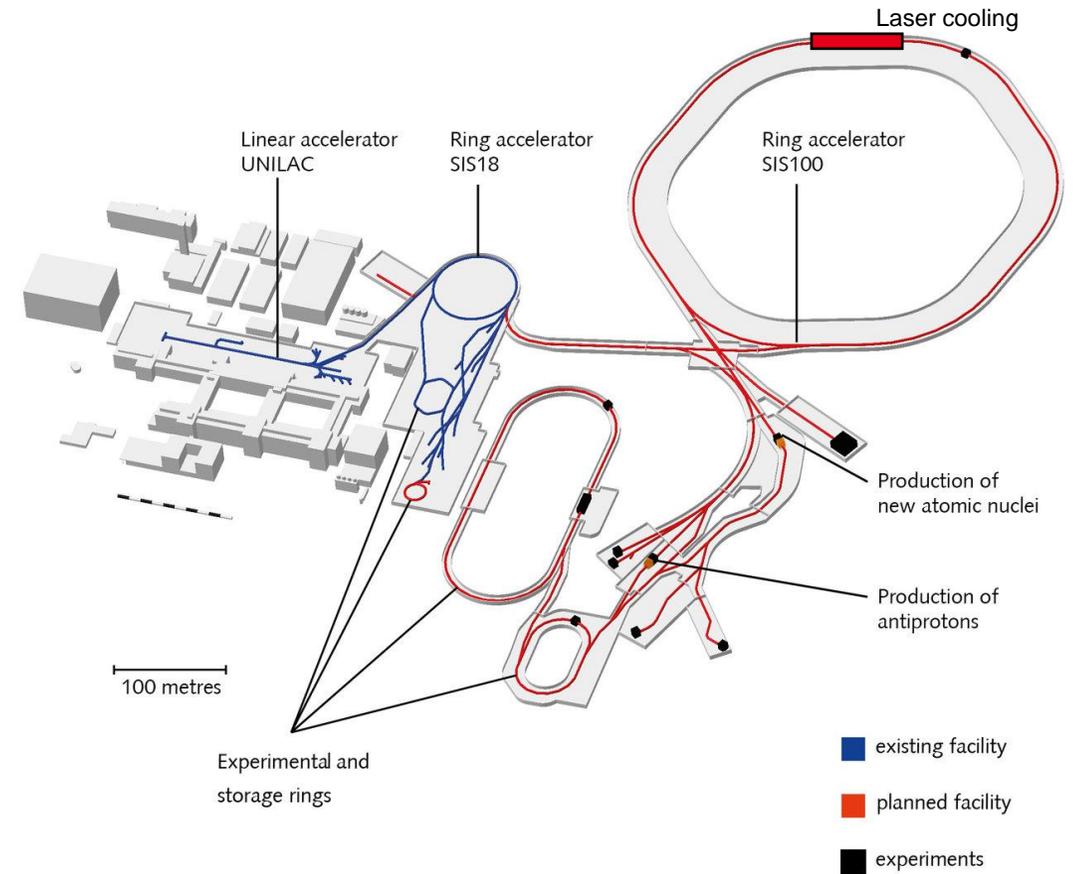
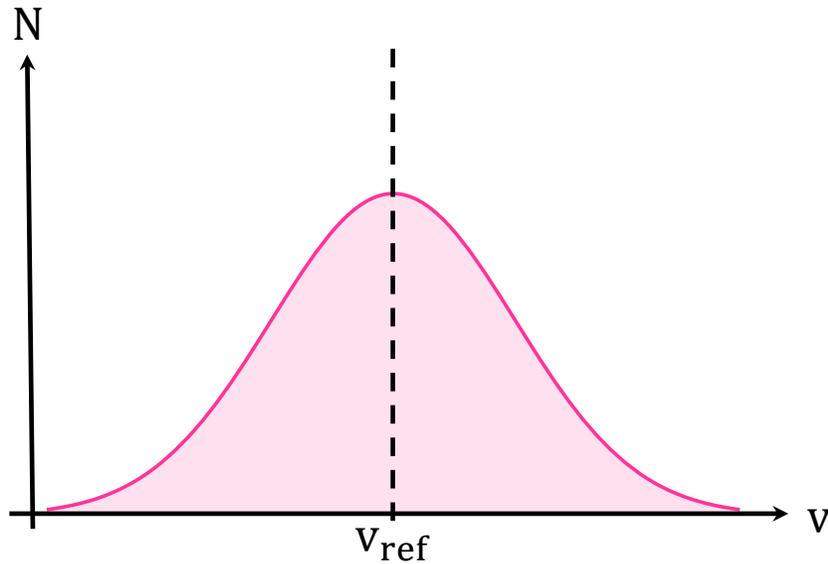




CHALLENGES OF LASER COOLING AT SIS100: UV SYSTEMS AND OVERLAP IN 5D

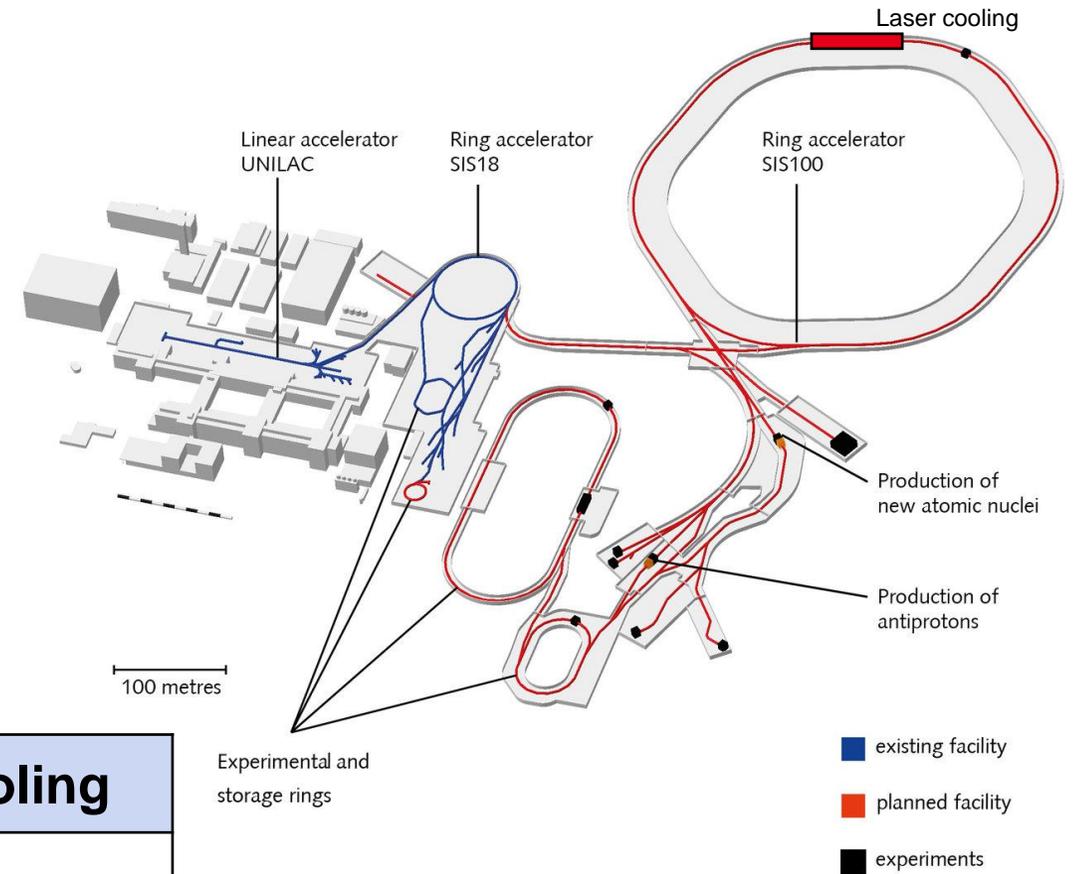
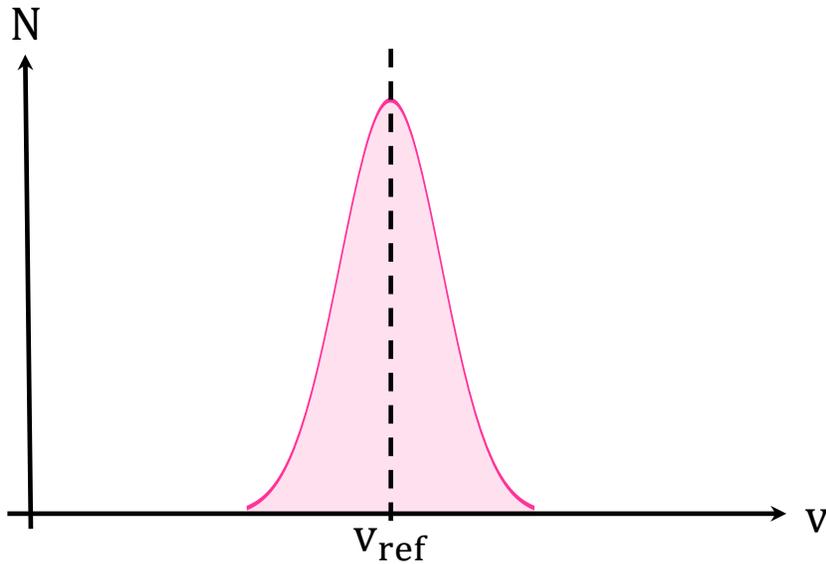
COOL'25 - **Denise Schwarz**, Jens Gumm, Benedikt Langfeld, Tamina Grunwitz,
Sebastian Klammes, Danyal Winters, Thomas Walther

COOLING IONS IN ACCELERATORS



https://www.gsi.de/en/researchaccelerators/fair/the_machine [2025]

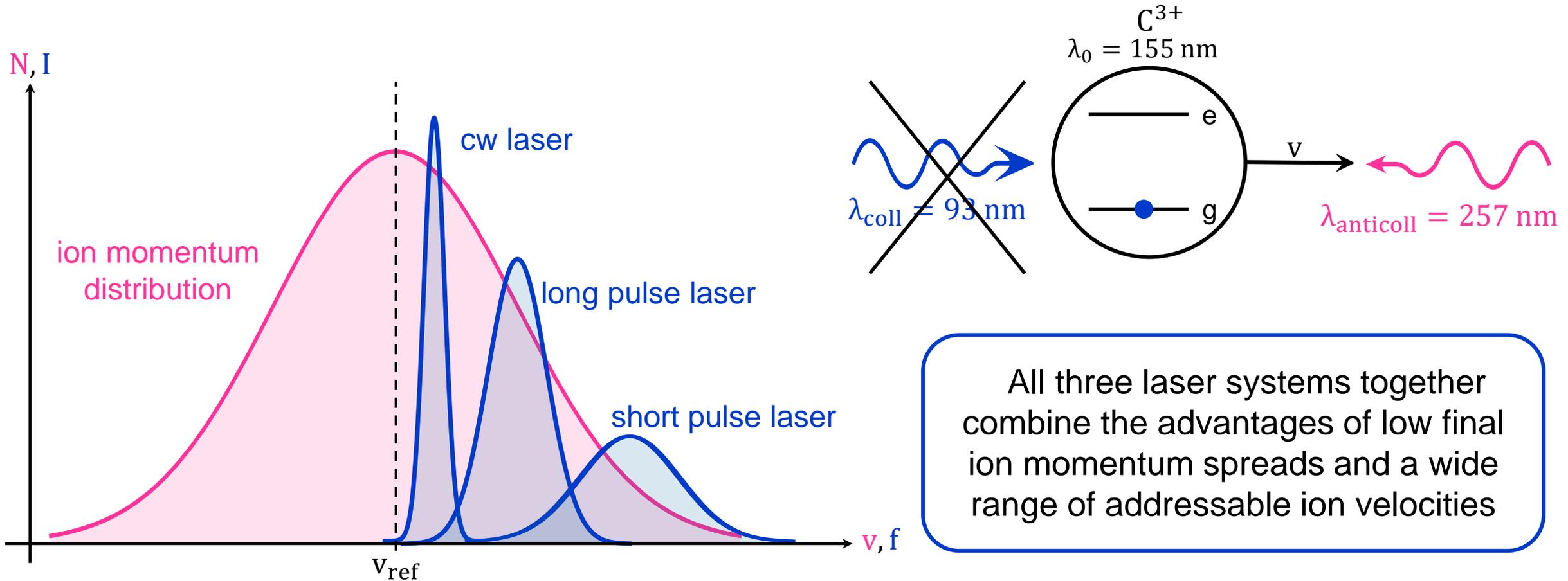
COOLING IONS IN ACCELERATORS



stochastic cooling	electron cooling	laser cooling
$\Delta p/p \approx 10^{-3}$	$\Delta p/p \approx 10^{-5}$	$\Delta p/p \approx 10^{-7}$
cooling time $\propto N_{ion}$	cooling force $\propto 1/\gamma$ cooling time $\propto \gamma^2$	cooling force $\propto \gamma$

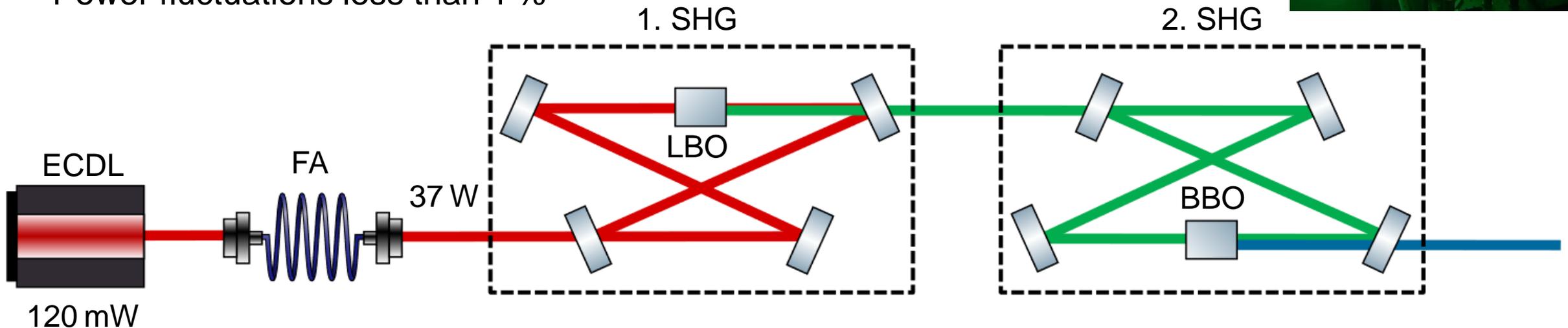
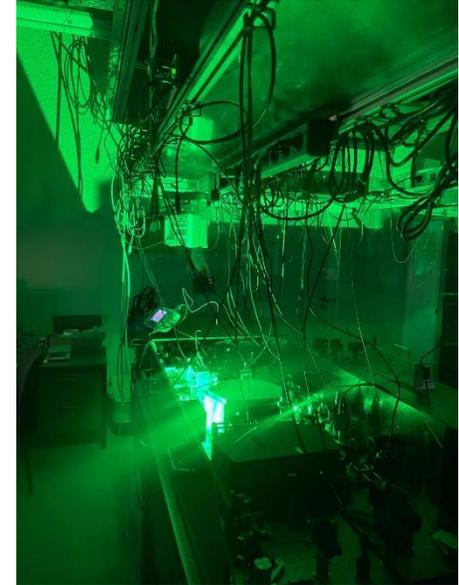
https://www.gsi.de/en/researchaccelerators/fair/the_machine [2025]

LASER COOLING OF RELATIVISTIC ION BEAMS

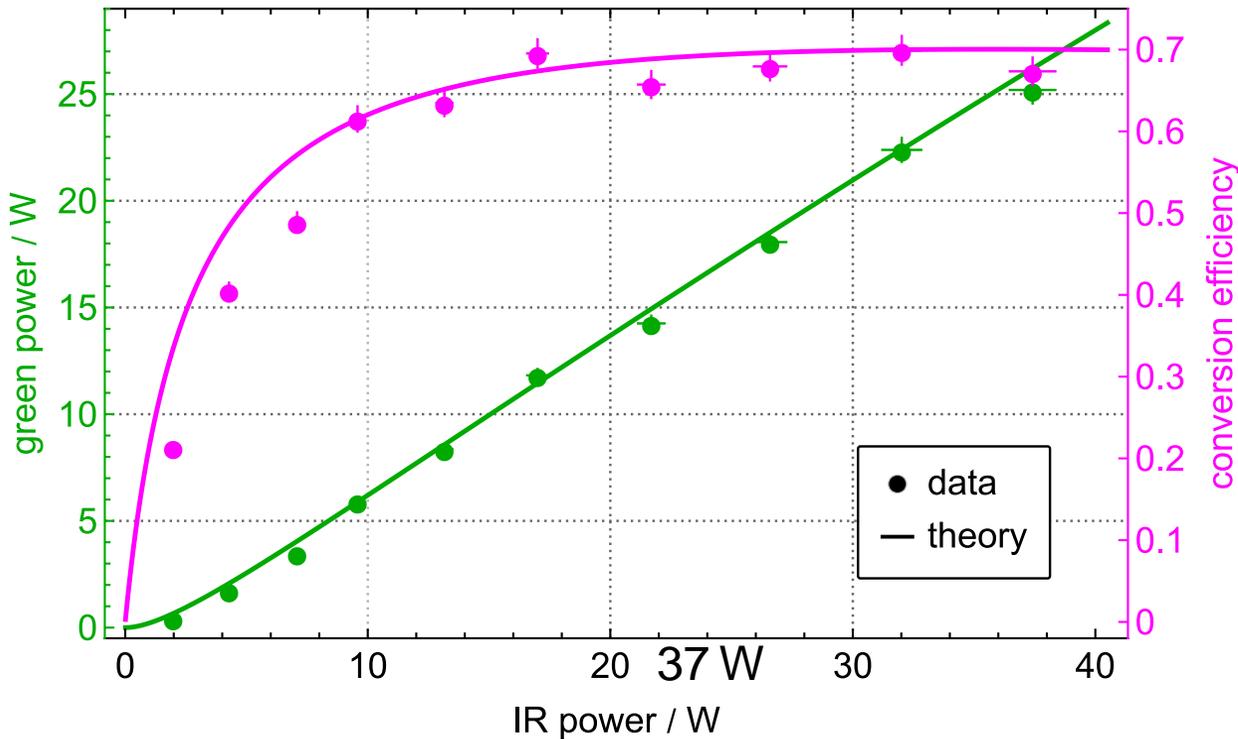


THE CW LASER SYSTEM

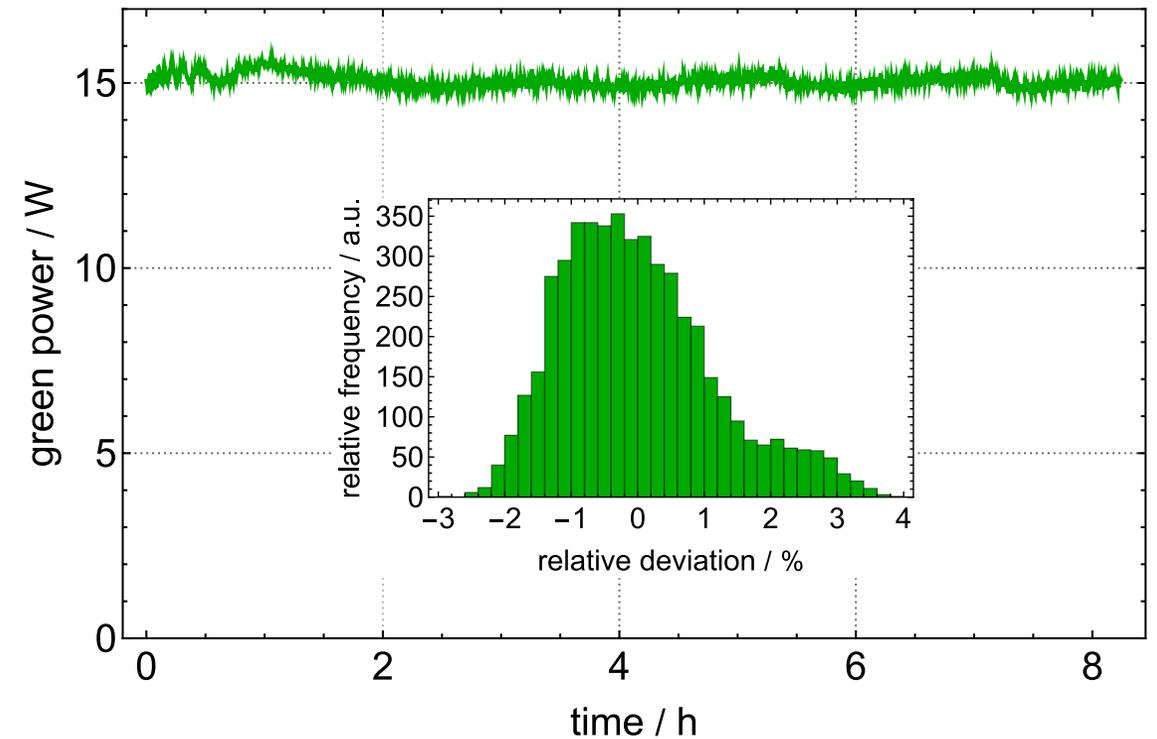
- Tunable in the range of 1027-1030 nm
- Small instantaneous linewidth of less than 1 MHz
- High output powers of at least 15 W in the IR, 5 W in the green and 1 W in the UV spectral range
- Power fluctuations less than 1 %



FREQUENCY CONVERSION TO THE GREEN SPECTRAL RANGE

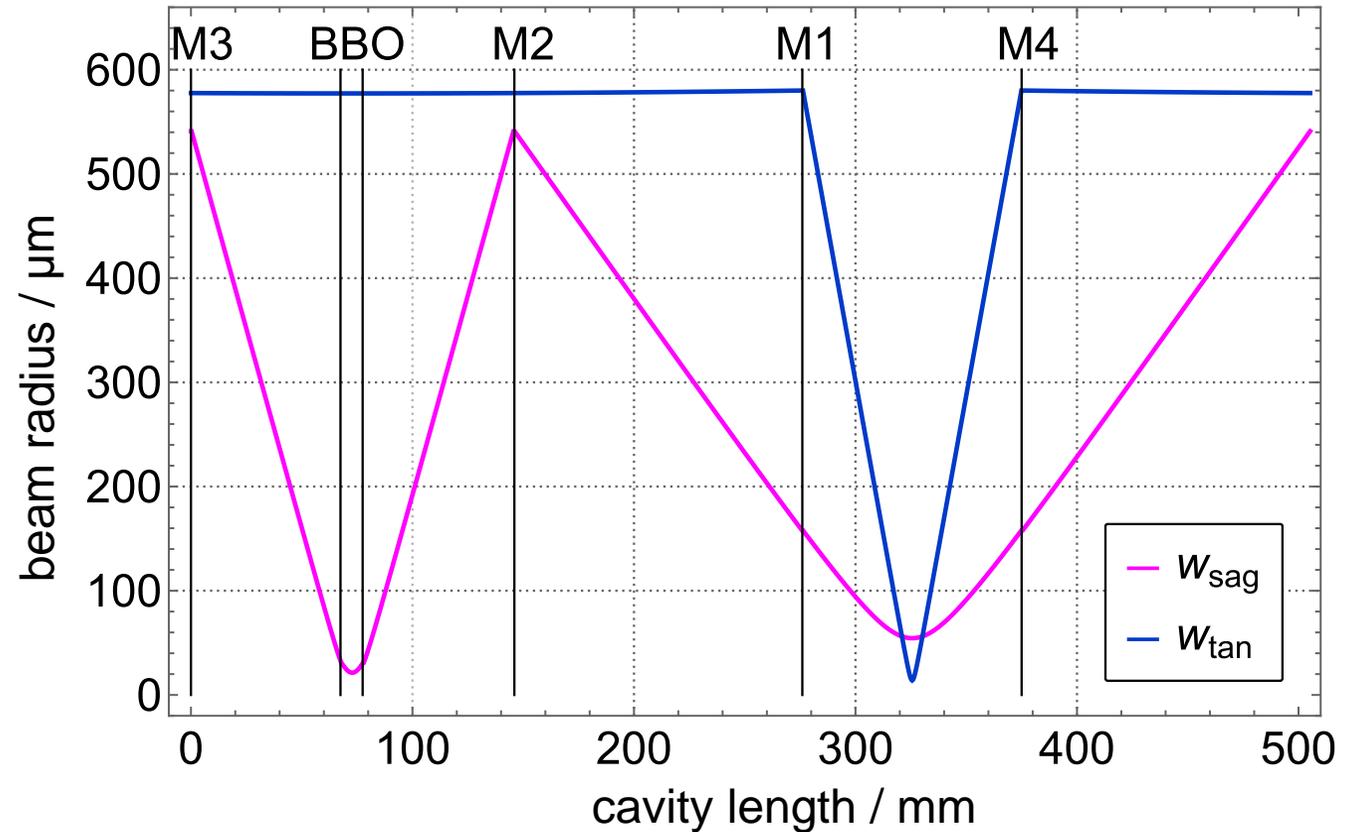
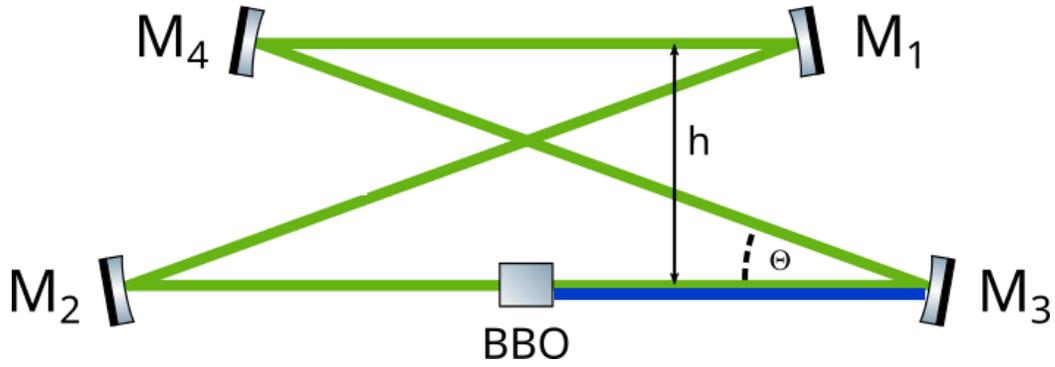


$P = 25.19 \text{ W} \pm 0.63 \text{ W}$
 $\eta = 70 \%$



$P = 15.0 \text{ W}$
 $\sigma = 124 \text{ mW} (0.8 \%)$

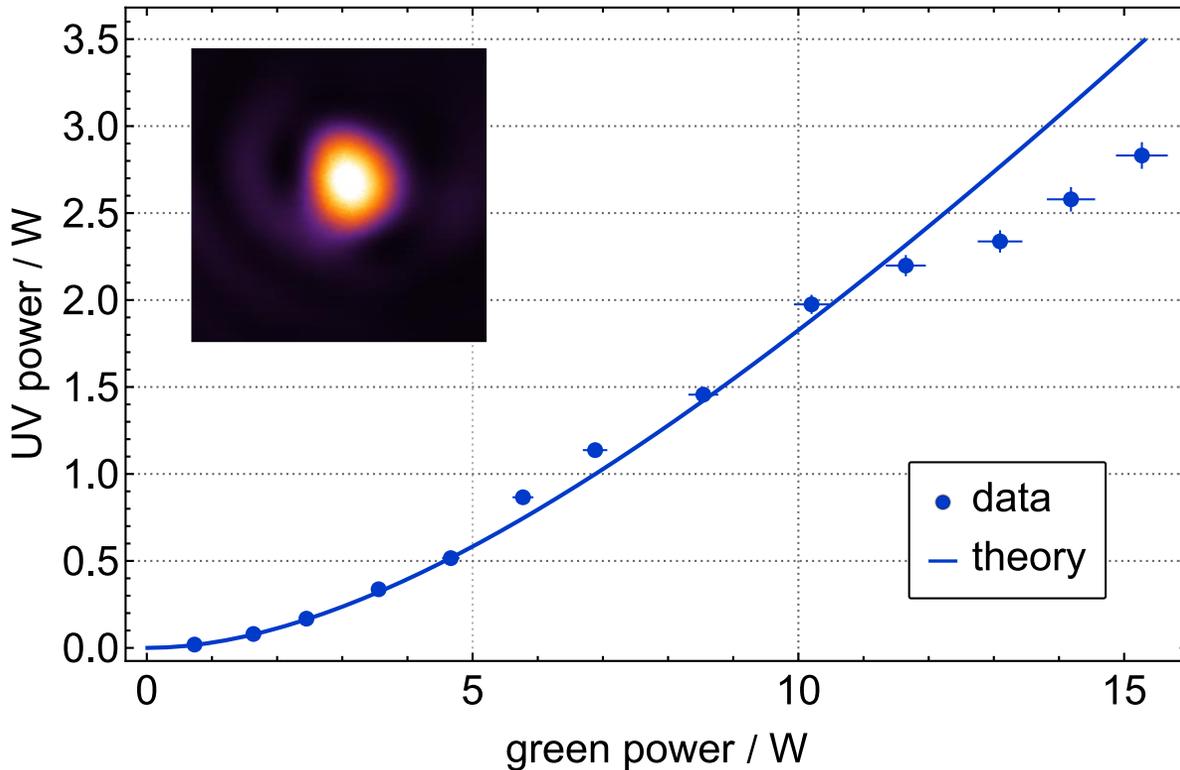
ELLIPTICAL FOCUSING CAVITY



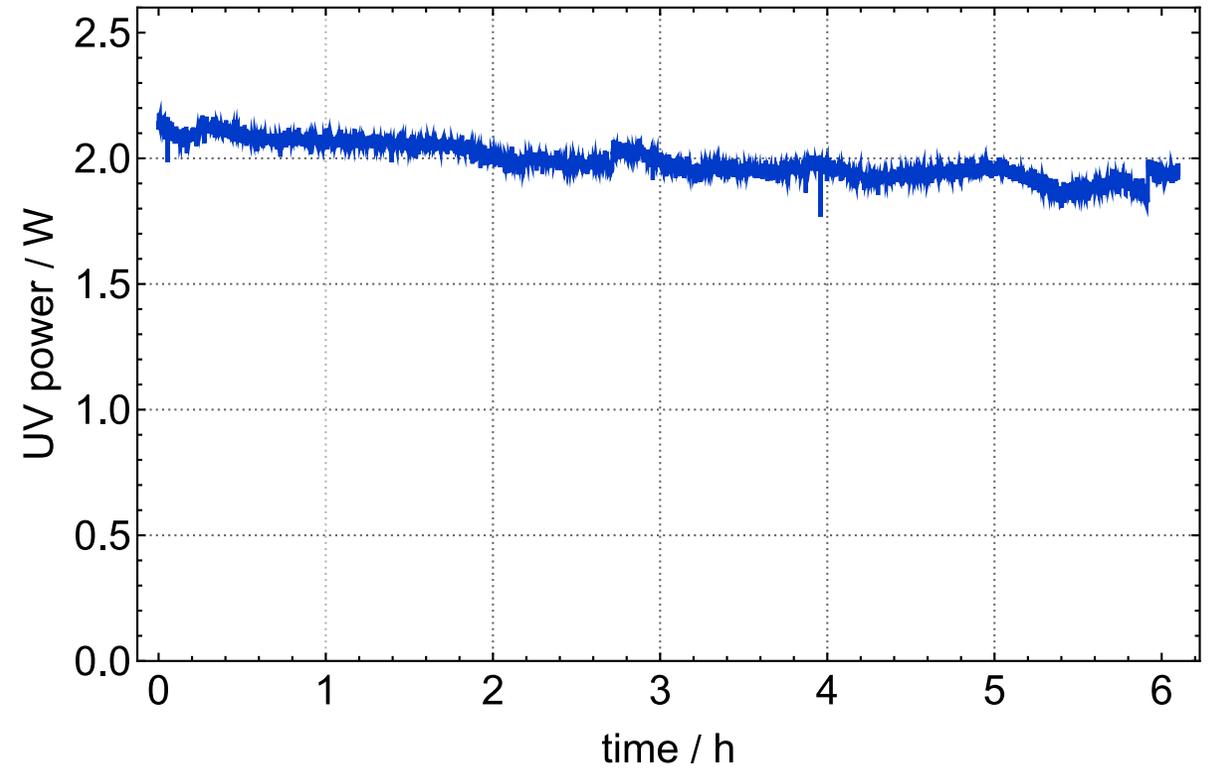
New elliptical focusing cavity :

- Beam waist $21 \mu\text{m} \times 577 \mu\text{m}$
- Theoretical output power 4.5 W

FREQUENCY CONVERSION TO THE UV SPECTRAL RANGE



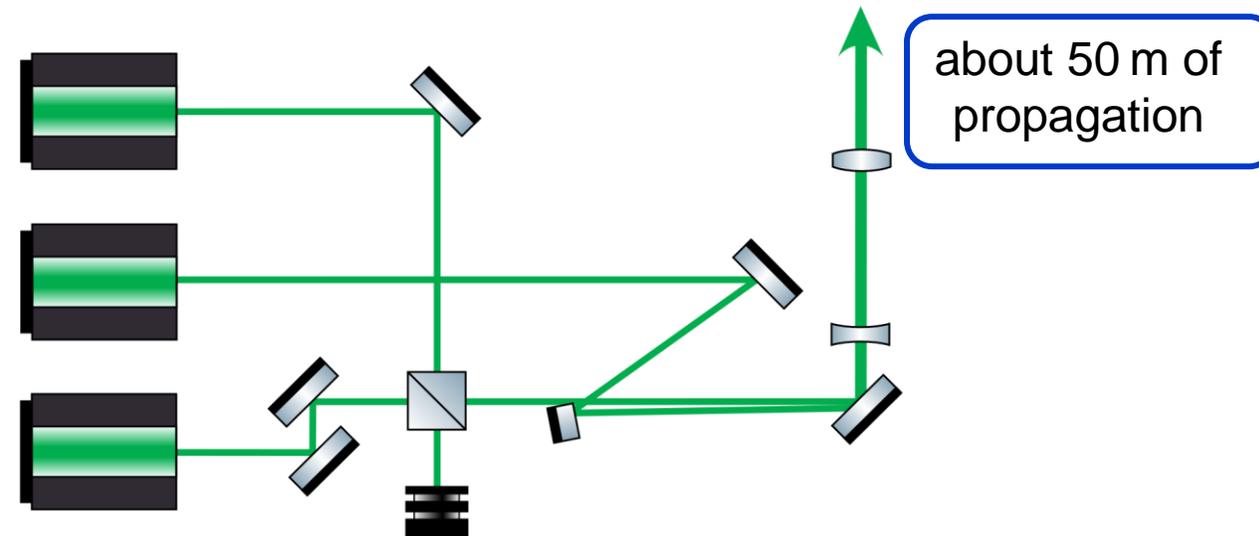
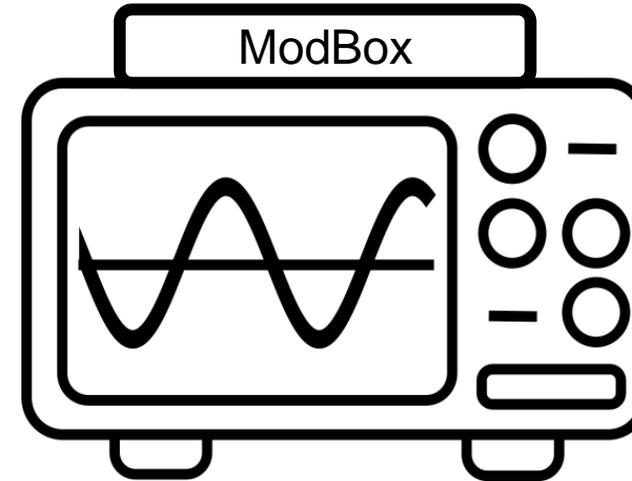
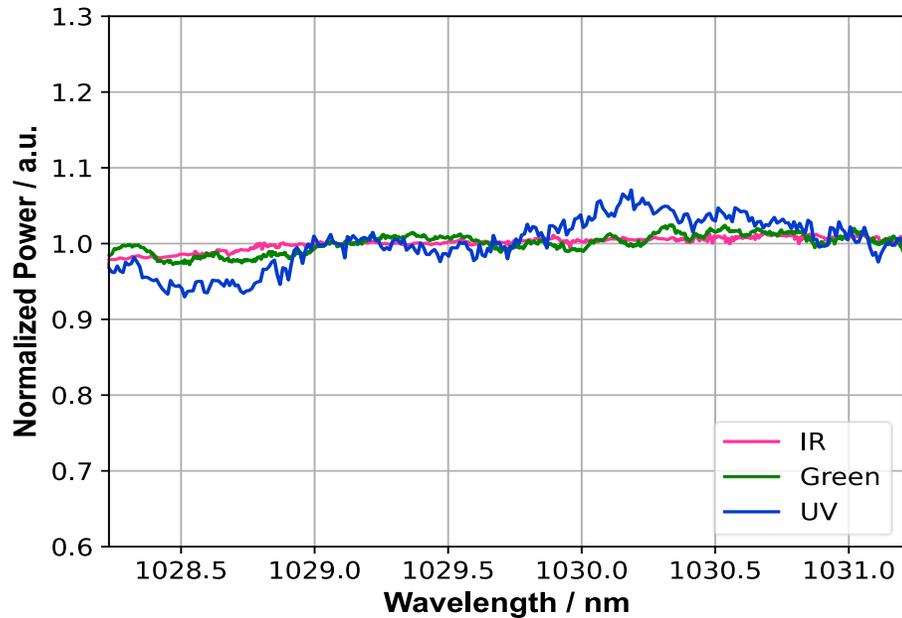
$P = 2.83 \text{ W} \pm 0.07 \text{ W}$



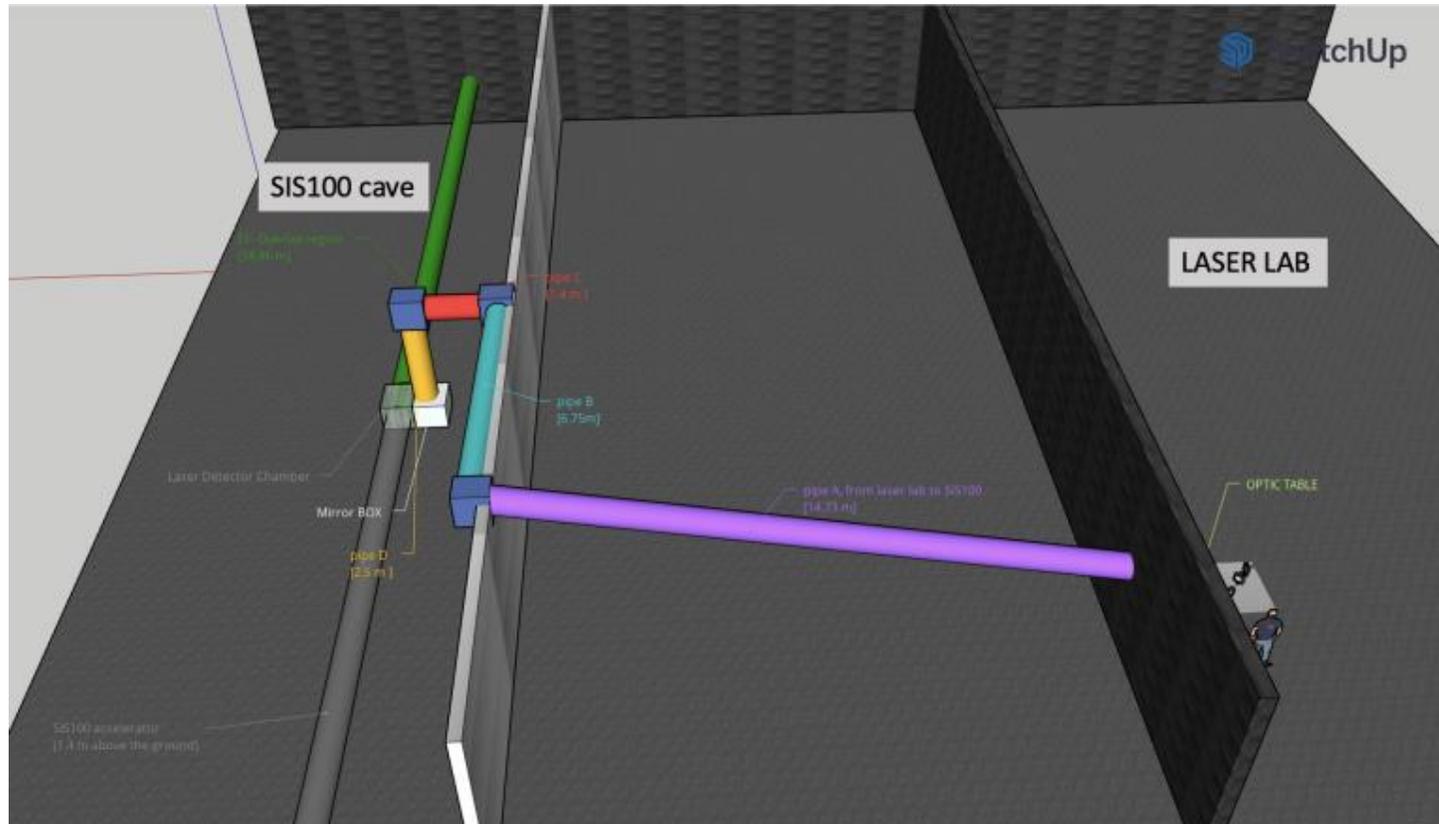
$P = 2.0 \text{ W}$
 $\sigma = 70 \text{ mW} (3.5 \%)$

OVERLAP IN 5D

- Energy overlap → Tunability
- Timing for the pulsed laser systems
- 3D spatial overlap with the ions

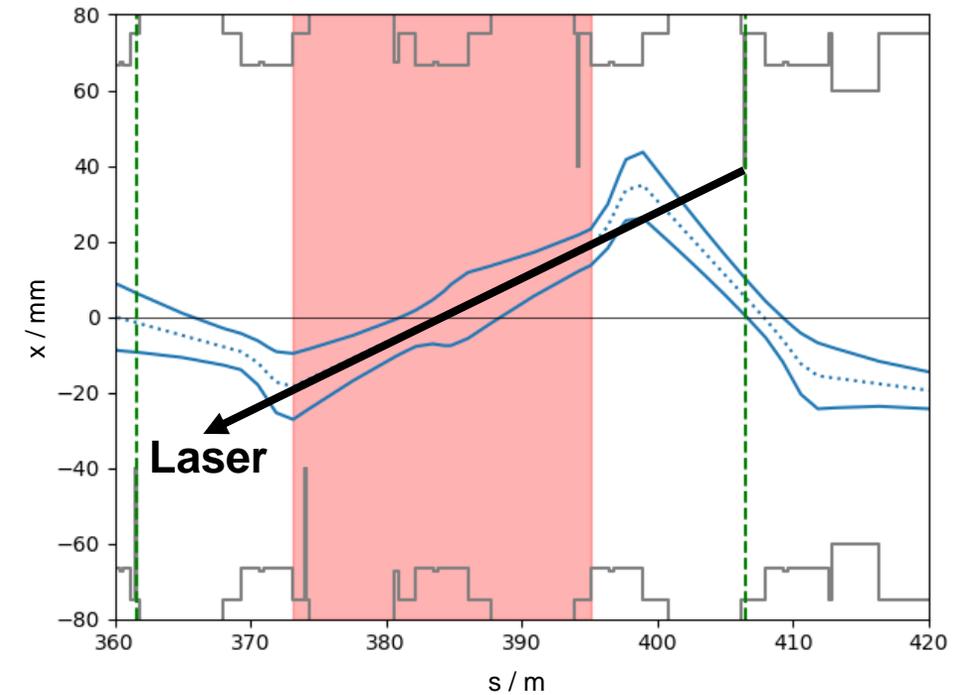


BEAM AT THE SIS100



Personal communication D. Winters

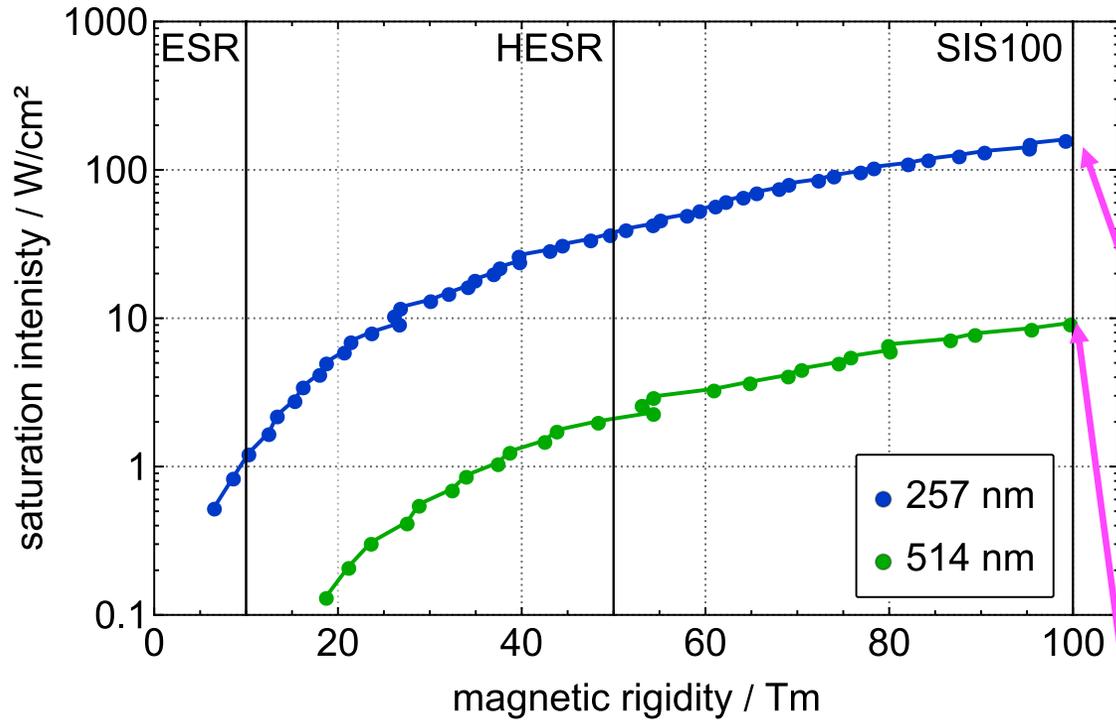
total distance over 60 m



LITHIUM-LIKE IONS

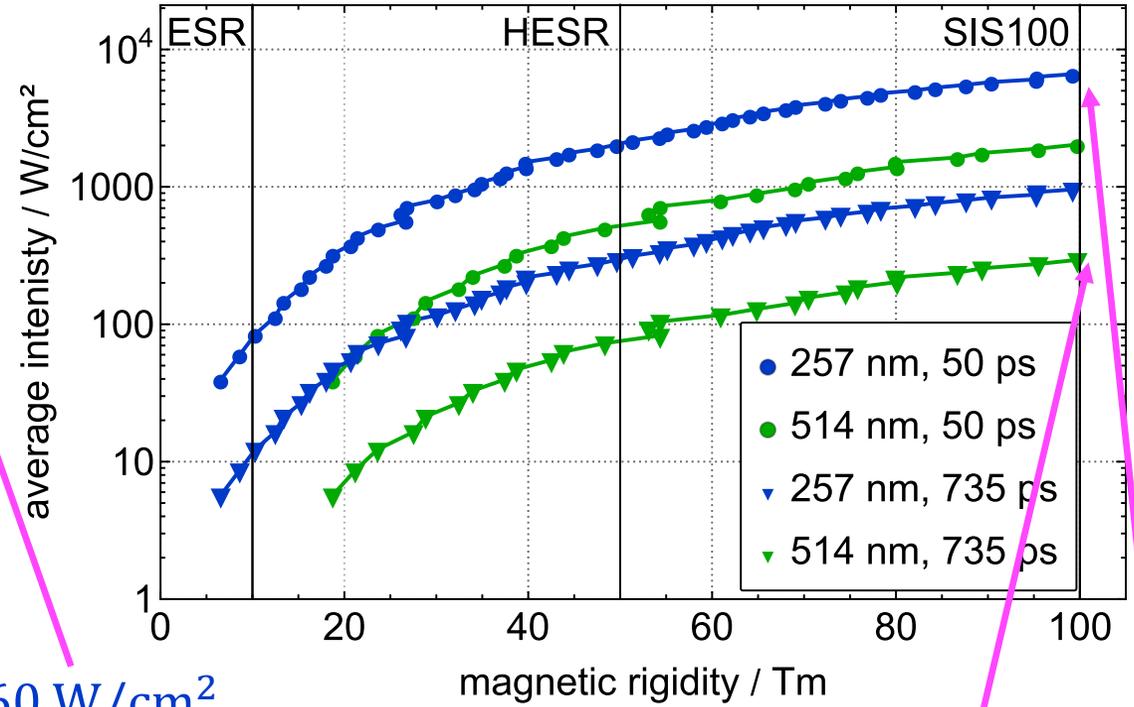
$$I_s = I_0 \cdot \frac{1}{\gamma^2(1 + \beta^2)} = \frac{2\pi^2 \hbar c}{3\lambda_{\text{anticoll}}^3 \tau} \cdot \gamma(1 + \beta)$$

$$I_{\text{avg}} = I_s \cdot f_{\text{rep}} \cdot V_{\text{puls}} \cdot \frac{\tau^2}{\tau_{\text{puls}}} \cdot \frac{1 + \beta}{1 - \beta}$$



160 W/cm²

10 W/cm²



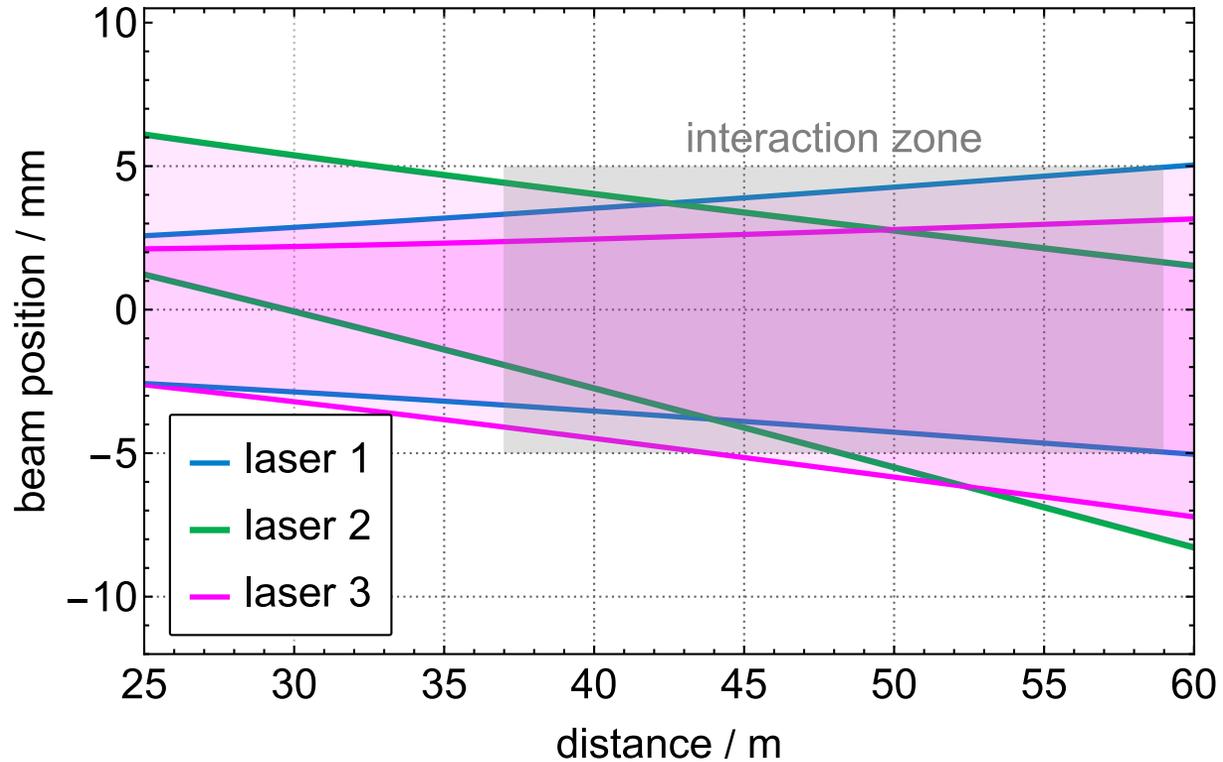
6610 W/cm²

294 W/cm²

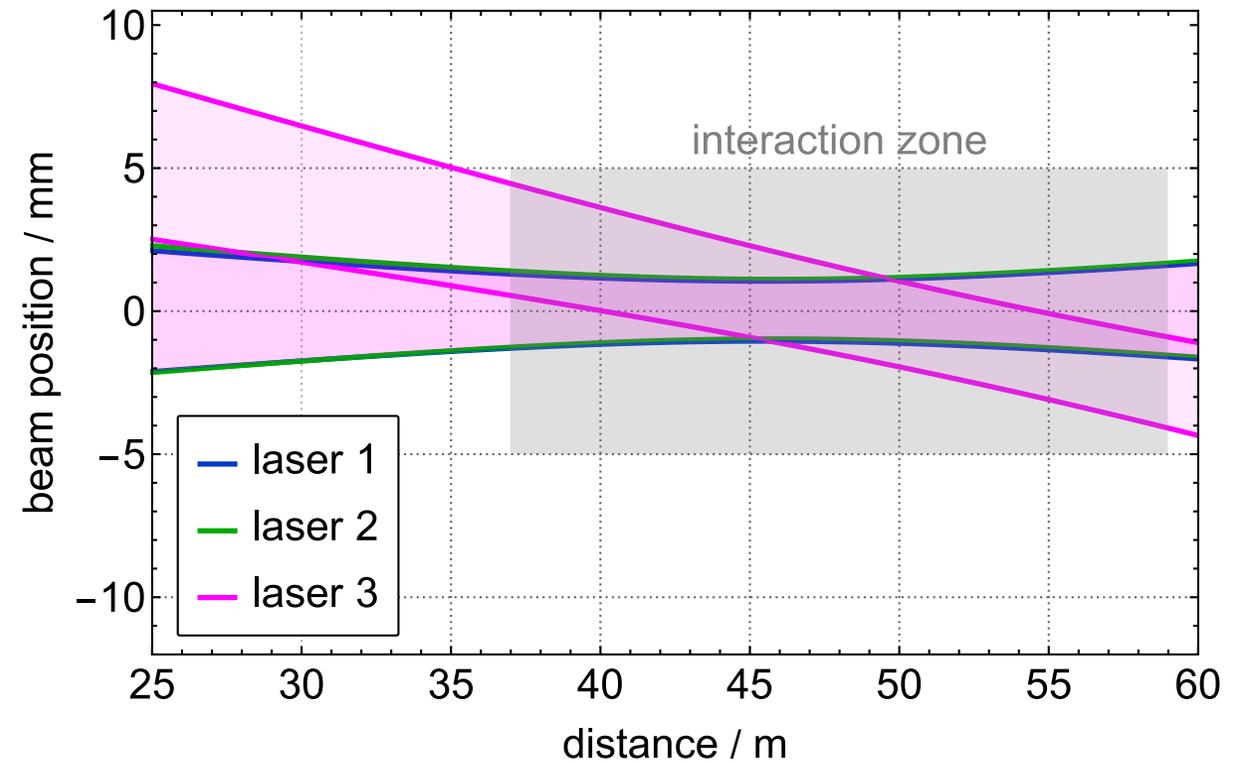
Data taken from: Transition rates for lithium-like ions, sodium-like ions, and neutral alkali-metal atoms, Johnson et al.

SPATIAL OVERLAP

Green spectral range



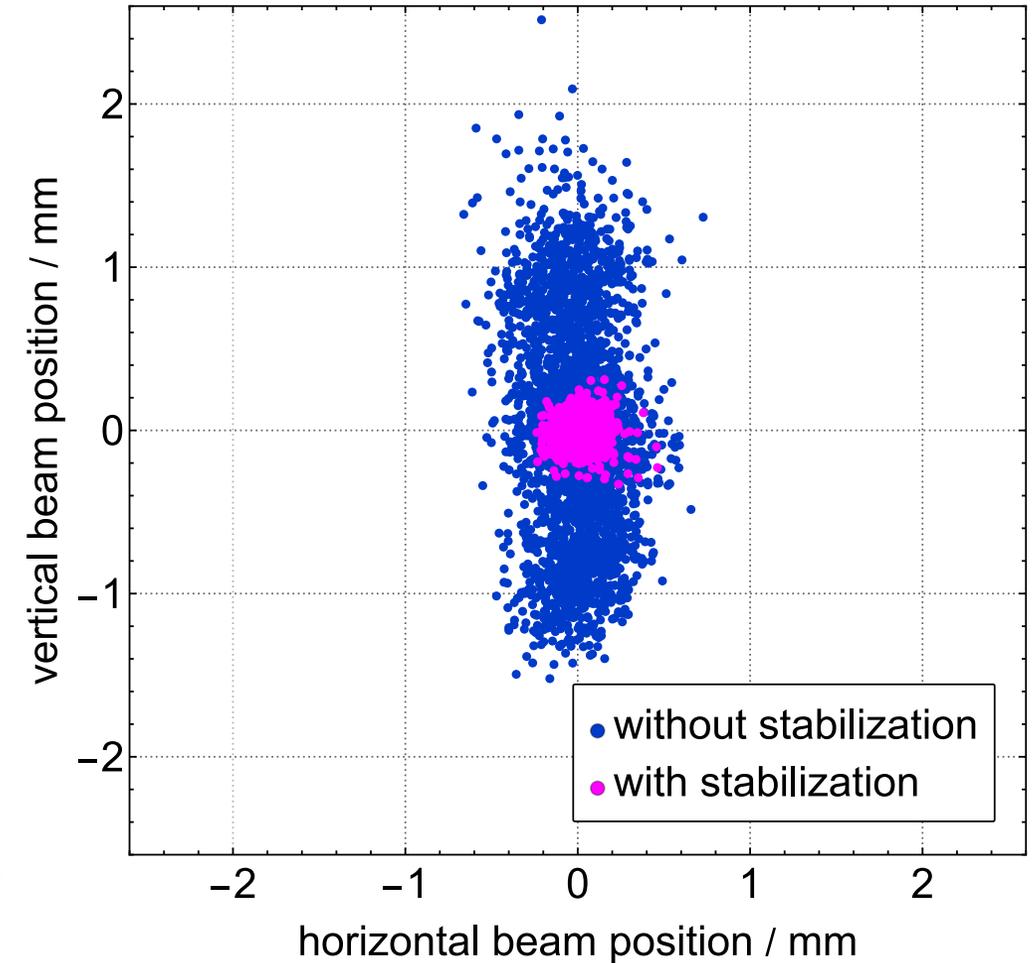
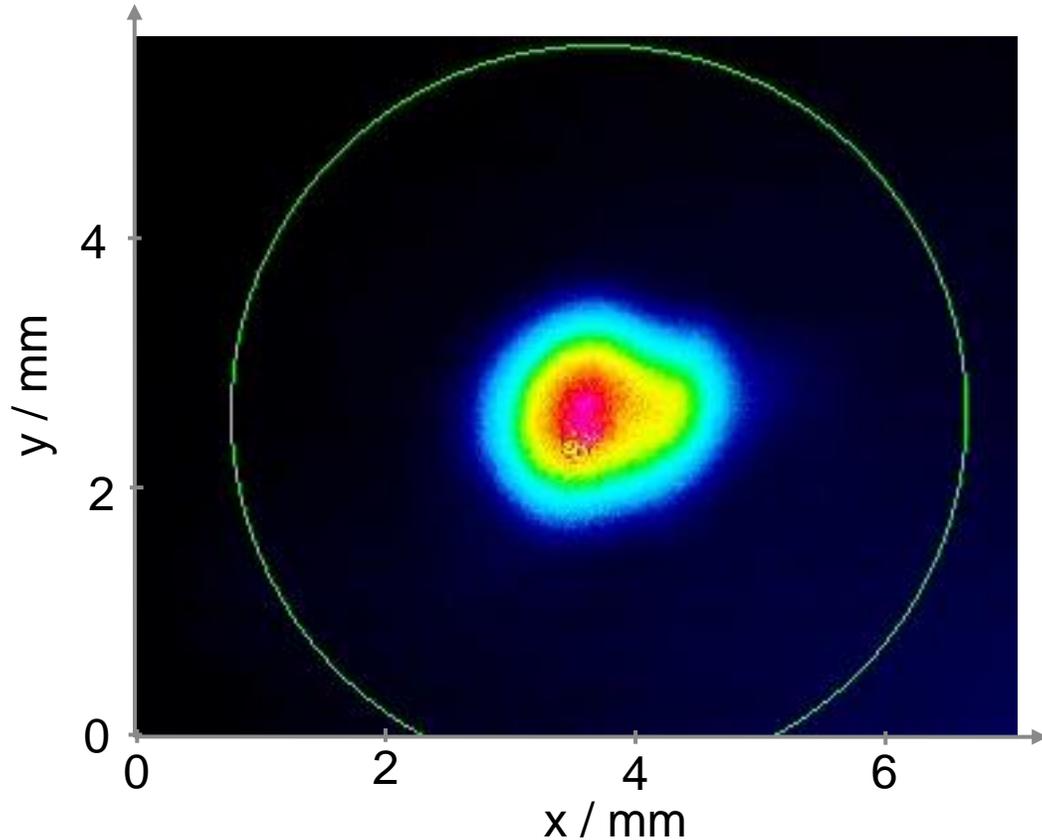
UV spectral range



cw laser: 64 W/cm^2

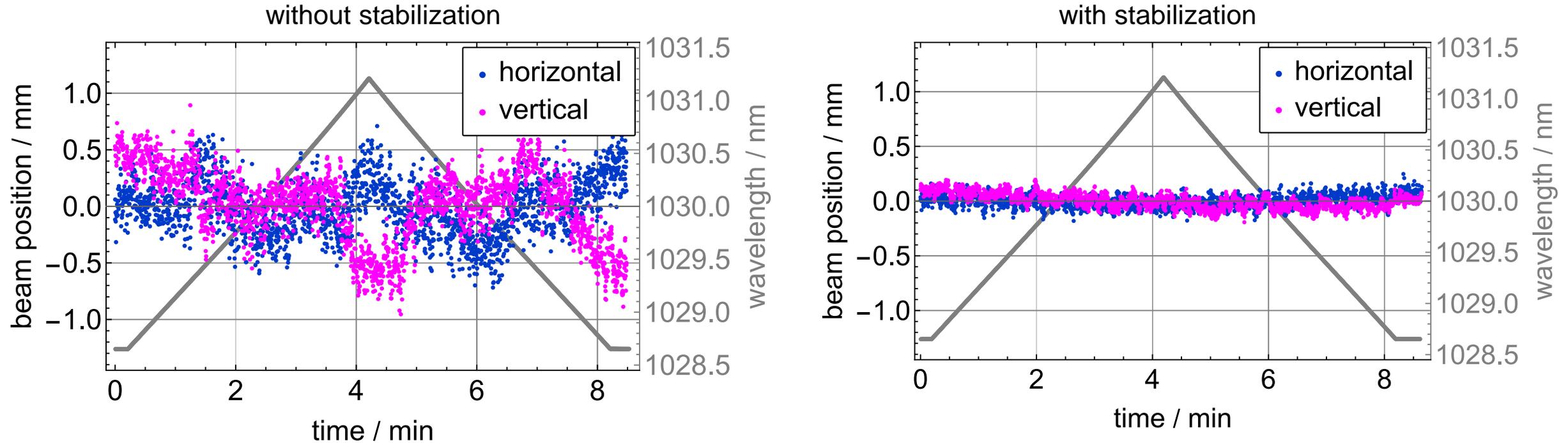
pulsed laser: 159 W/cm^2

ACTIVE BEAM STABILIZATION



Active beam stabilization decreases fluctuations due to vibrations, air pressure variations, etc.

ACTIVE BEAM STABILIZATION



Active beam stabilization during wide scan of pulsed laser system decreases fluctuations

SUMMARY AND OUTLOOK

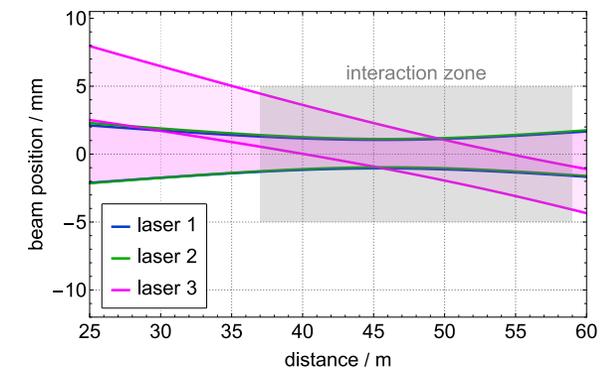
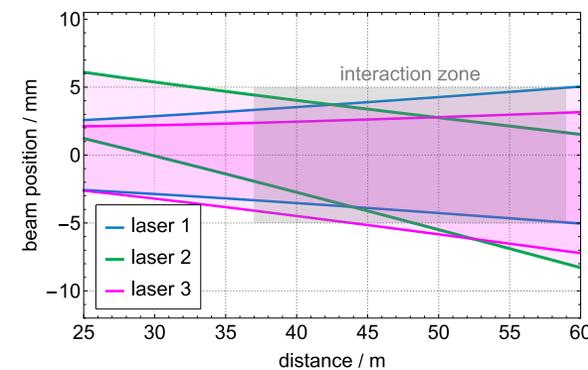
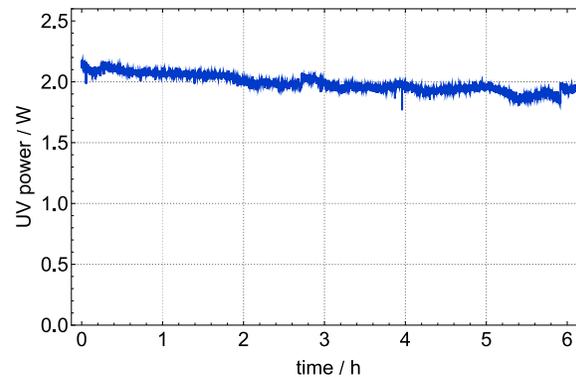
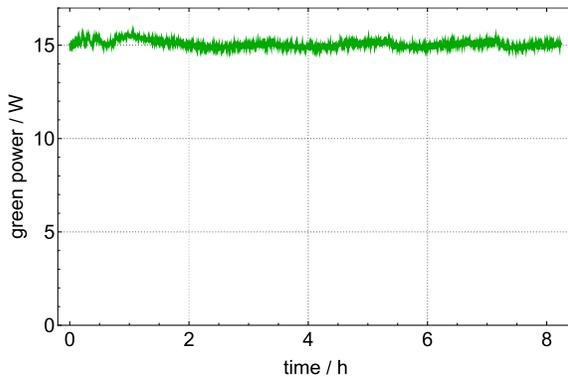
cw laser system specs

Spectral range	IR	Green	UV
Power	37 W	25 W	2.8 W

- Long term stable output in the green and UV

- Energy overlap → Tunability
- Timing for the pulsed laser systems
- 3D spatial overlap with the ions

A laser cooling experiment is crucial to test the laser systems and their overlap, allowing for potential optimizations in preparation for SIS100 operations.



THANK YOU!



GEFÖRDERT VOM



Bundesministerium
für Forschung, Technologie
und Raumfahrt

