Exploring Interferometry Diagnostics for Optical Stochastic Cooling at FAST/IOTA

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Introduction

- Stochastic Cooling is a technique used in particle accelerators which fundamentally compresses charged particles into a finer beam with less energy spread and angular divergence. It is used to improve beam quality and is traditionally operated in a microwave regime.
- Optical Stochastic Cooling (OSC) is based on the same principles but uses smaller optical wavelengths and leverages optical radiation and high-precision feedback to cool the particles more efficiently and cool much denser beams.
- One of the most important requirements in OSC is the preservation of the optical radiation's phase information.

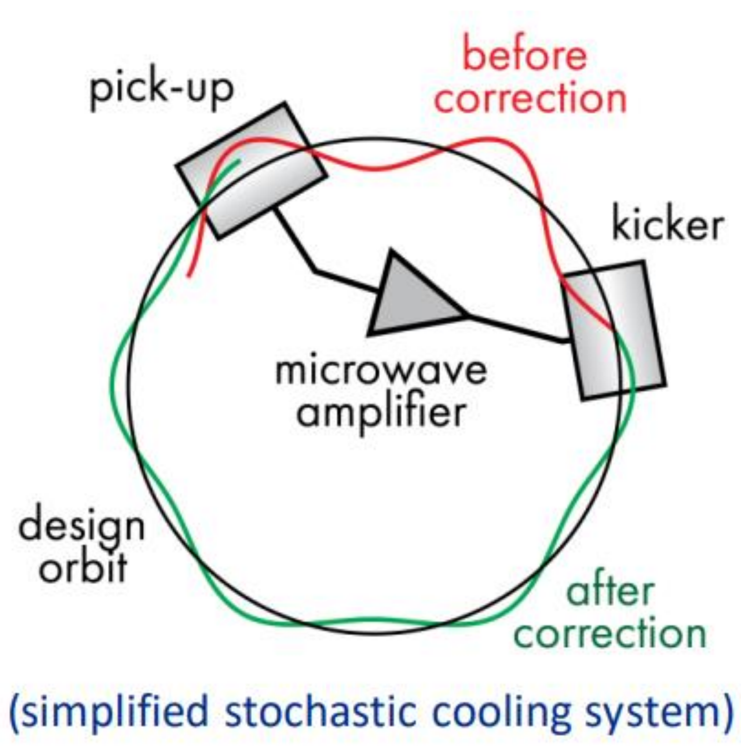

Fig 1. Traditional simplified stochastic cooling system method.

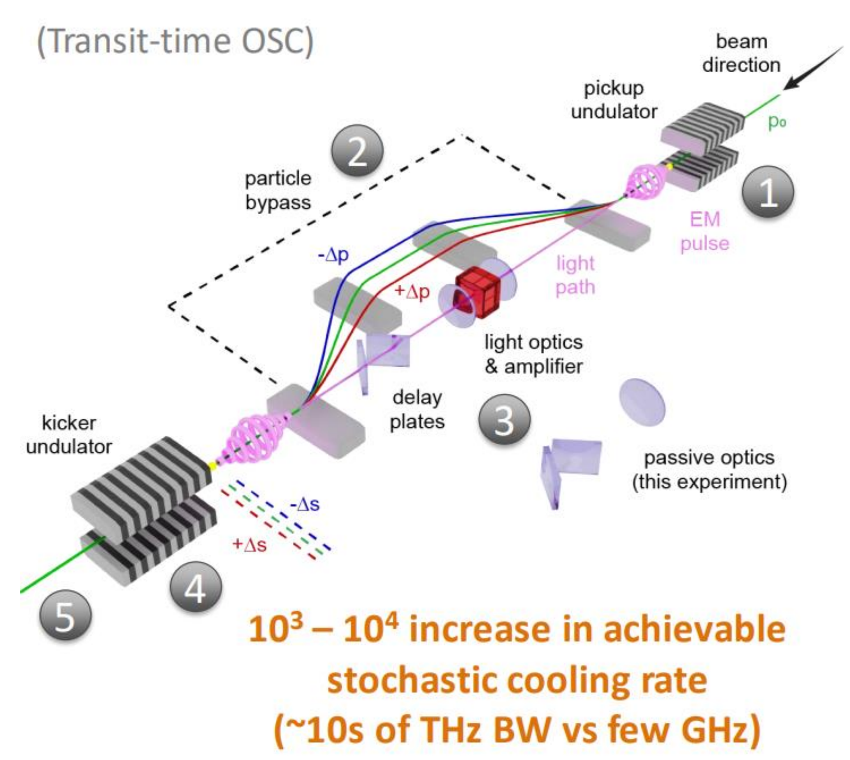

Fig 2. Conceptual schematic of a transit-time optical stochastic cooling system.

Results & Discussion

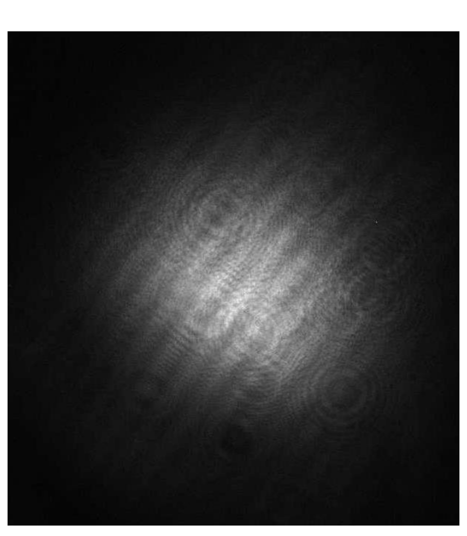

Fig 5. Patten without glass slide.

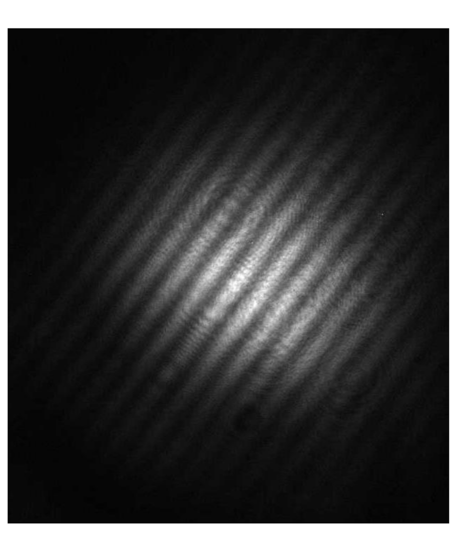

Fig 6. Patten with three glass slides.

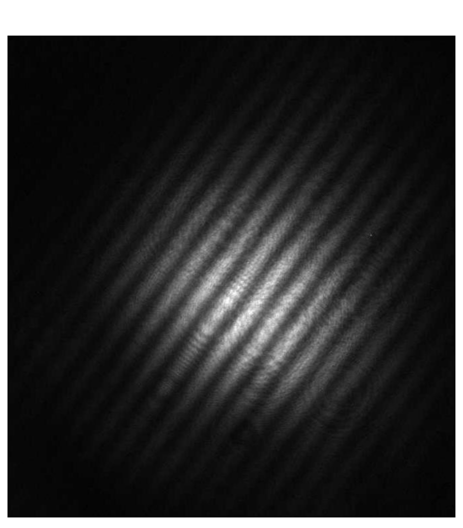

Fig 7. Interference Patten at 280°

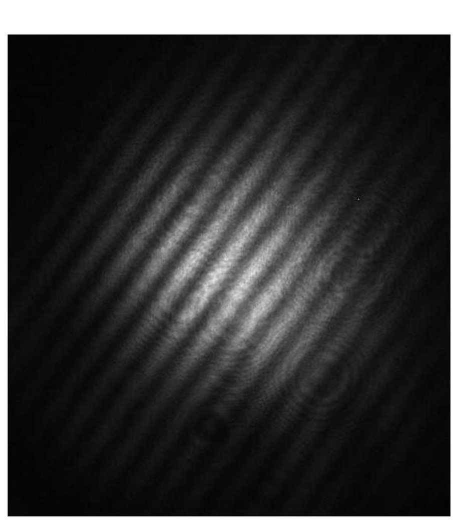

Fig 8. Interference Patten at 260°

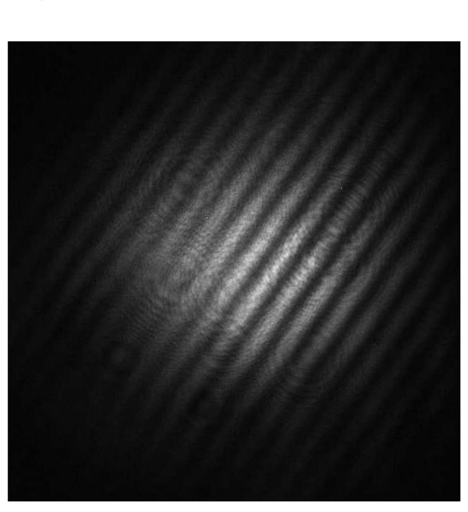

Fig 9. Interference Patten at 240°

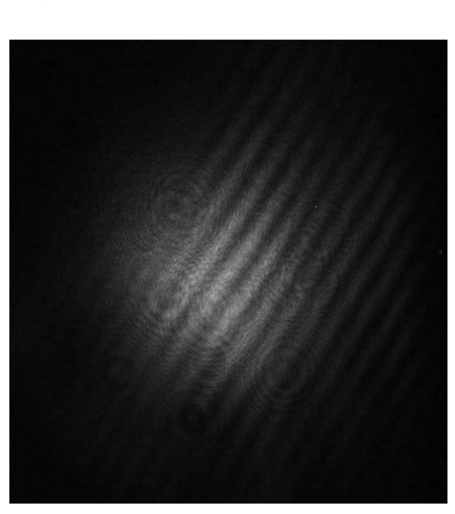

Fig 10. Interference Patten at 220°

- The MZI was built in the FAST laser lab and interference pattern were successfully observed.
- The introduction of glass slides in one arm of the MZI increases the optical path length and shifts the interference pattern.
- The glass slides can also be rotated to increase or decrease the amount of glass traversed by the light, as shown in Figures 7-10.
- Reduced fringe contrast in some images is likely due to poor longitudinal overlap of pulses between the two arms.
- The basic concept is demonstrated, but better data quality and more systematic measurements would be required for quantitative analysis.

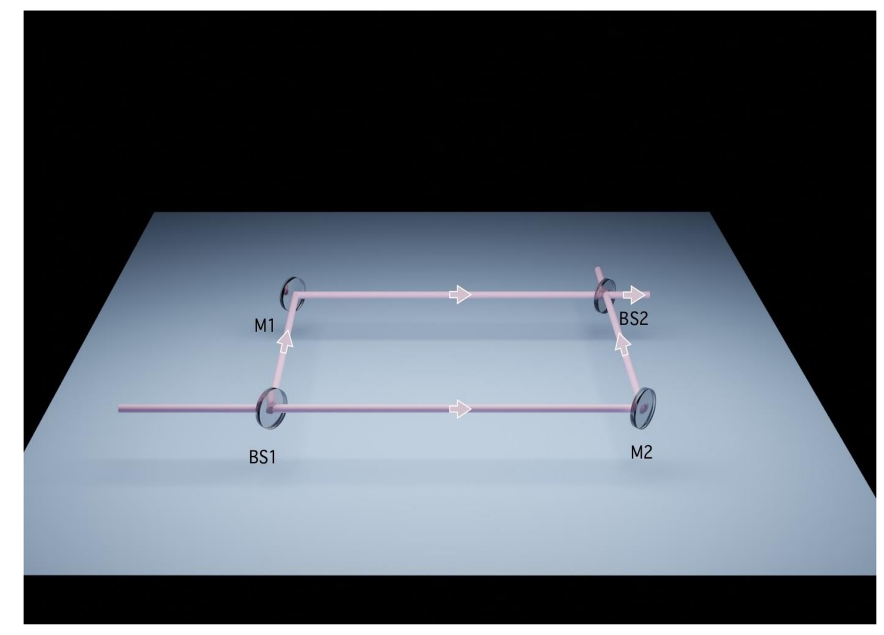

Fig.3: Schematic of the Mach-Zehnder Interferometer

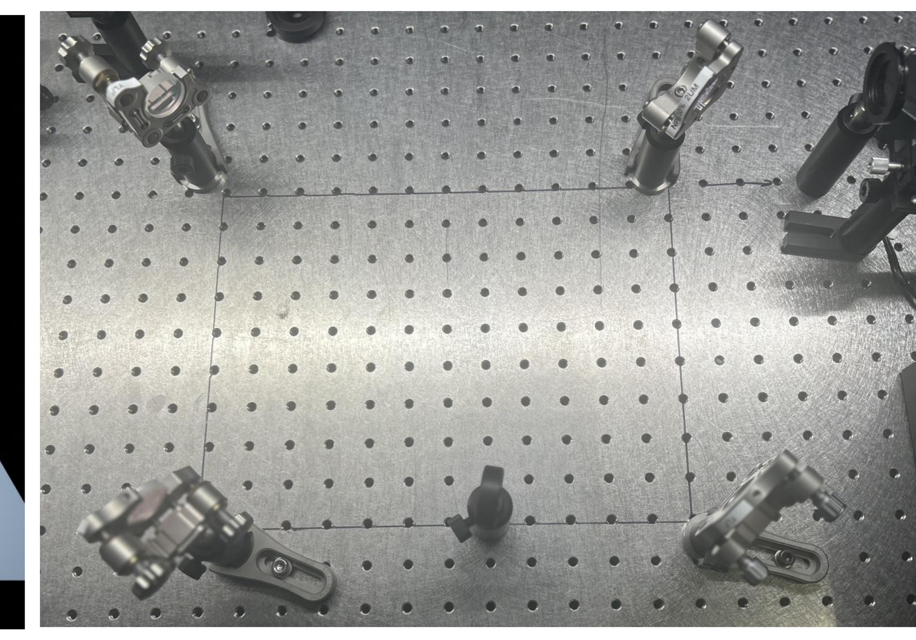

Fig 4. Real application of the Mach-Zehnder Interferometer

Interferometry for measuring phase distortions

- A Mach-Zehnder Interferometer (MZI), shown schematically in Figure 3, can be used to measure the phase difference between two optical paths.
- In this project a prototype MZI (Figure 4) was built to validate instrumentation and procedures for phase-measurements in the OSC experiment.
- A near infrared pulse laser (1053nm) is split into two parts by a beamsplitter and then recombined by a second beamsplitter. The path differences result in an interference pattern, which is detected using a camera. If the phase of the light in one arm is changed, for example by additional path length or by an amplification process, then this will appear as a shift in the fringes of the interference pattern.
- In one method, 1-mm thick glass slides are inserted in one of the arms and data is taken on the change in interference between each slide.
- In the second method, Four glass slides are rotated in front of the beam starting at 280° and decreasing by 10 degrees until interference is no longer visible.

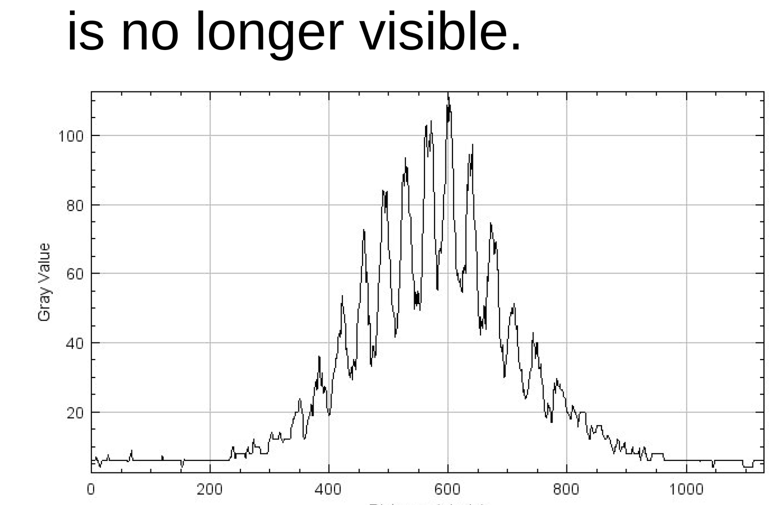

Fig 11. Plot of Fringe Pattern with two glass slides

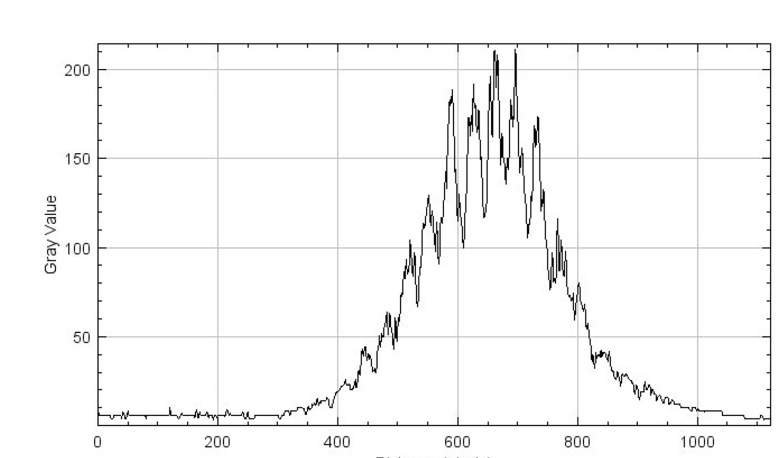

Fig 12. Plot of Fringe Pattern with three glass slides.

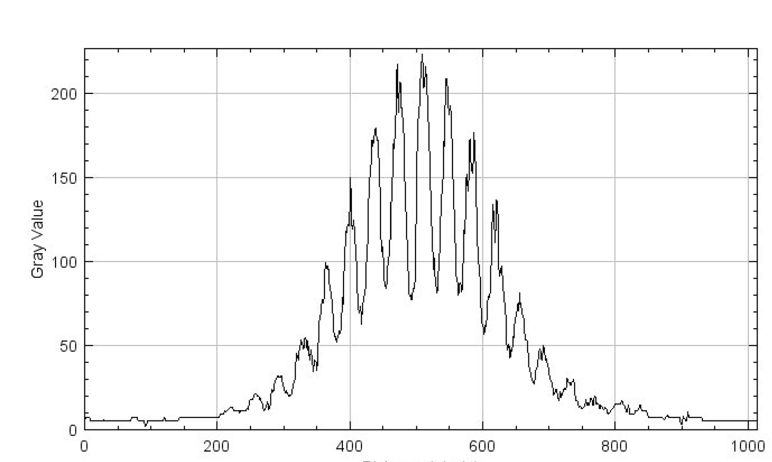

Fig 13. Plot of Fringe Pattern with four glass slides at 280°

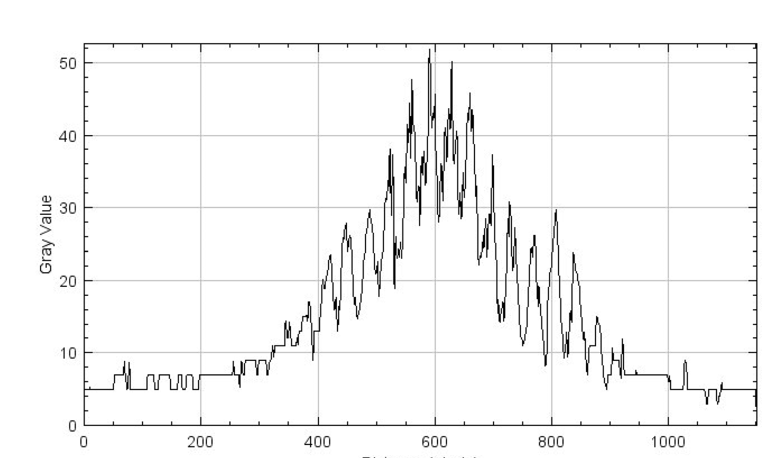

Fig 12. Plot of Fringe Pattern with four glass slides at 230°

Conclusion & Future Work

In preparing for the upcoming Optical Stochastic Cooling experiment, a Mach-Zehnder interferometer will be employed to measure phase distortions of the amplified light as a function of amplifier gain. A basic MZI system was prototyped to gain familiarity with the instrumentation and procedures for the required phase measurements. Interference was observed using a 1053-nm pulsed laser, and glass slides were then used to modify the relative phase (delay) of the interferometer's two arms. For the upcoming 2-mm OSC measurements, automation of the fringe measurements using diode detectors and closed-loop piezoelectric stages is needed.

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