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DESIGN OF THE 2-STAGE LASER TRANSPORT FOR THE LOW ENERGY RHIC ELECTRON COOLING (LEReC) DC PHOTOGUN*

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Abstract

The electron beam for the recently constructed Low Energy RHIC electron Cooler (LEReC) at Brookhaven National Laboratory is generated by a high-power fiber laser [1] illuminating a photocathode. The pointing stability of the low-energy electron beam, which is crucial to maintain within acceptable limits given the long beam transport, is highly dependent on the center-of-mass (CoM) stability of the laser spot on the photocathode. For reasons of accessibility during operations, the laser itself is located outside the accelerator tunnel, leading to the need to propagate the laser beam 34m via three laser tables to the photocathode. The challenges to achieving the required CoM stability of 10 microns on the photocathode thus requires mitigation of vibrations along the transport and of weather- and season-related environmental effects, while preserving accessibility and diagnostic capabilities with proactive design. After successful commissioning of the full transport in 2018/19, we report on our solutions to these design challenges.

INTRODUCTION

The Low Energy RHIC electron Cooling (LEReC) project is the first to demonstrate electron cooling using RF-accelerated bunched electron beams. It successfully completed commissioning in 2018 [2] and subsequently demonstrated cooling of gold ions for collisions in the Relativistic Heavy Ion Collider (RHIC) at the Brookhaven National Laboratory (BNL) in 2019 [3].

LEReC is located inside the RHIC radiation enclosure. The radiation levels, environmental conditions, and limited access during the accelerator run make it necessary to locate the drive laser outside the enclosure, about 30 m in optical distance from the LEReC electron gun. This circumstance makes a laser transport system necessary.

At the same time, the Center-of-Mass (CoM) stability of the laser spot on the aperture located next to the electron gun, which gets imaged to the photocathode to generate a desired truncated Gaussian profile, needs to be <50 µm rms, driven by the required CoM stability of the image (<10 µm rms) to allow the 100 m long electron beam transport required for cooling of both ion beams in RHIC with the same electron beam.

The laser transport constructed for LEReC successfully finished commissioning in 2018 with the addition of a camera-based feedback system [4] to correct for slow drifts due to weather-driven ground motion.

LEReC LASER TRANSPORT OVERVIEW

The laser transport system consists of a launch system located on the drive laser table in the laser trailer; a relay table located just inside the RHIC enclosure to lift the laser beam above the RHIC beam pipes; and a receiving gun table which holds the aperture that gets imaged onto the photocathode.

Laser tables along the transport host a light-tight enclosure and are interconnected via straight vacuum tubes that are not supported by the tables themselves. The laser beam is elevated or lowered by A-frames specifically designed to provide rigid support for mirrors.

Solid concrete blocks bind the relay and gun tables to the foundation of the accelerator. The drive laser table is not rigidly attached to the laser trailer, but rather held by five thermally insulated steel legs welded to two 21-metric-ton steel blocks located 34 in below ground.

Figure 1 shows a schematic of the transport system.

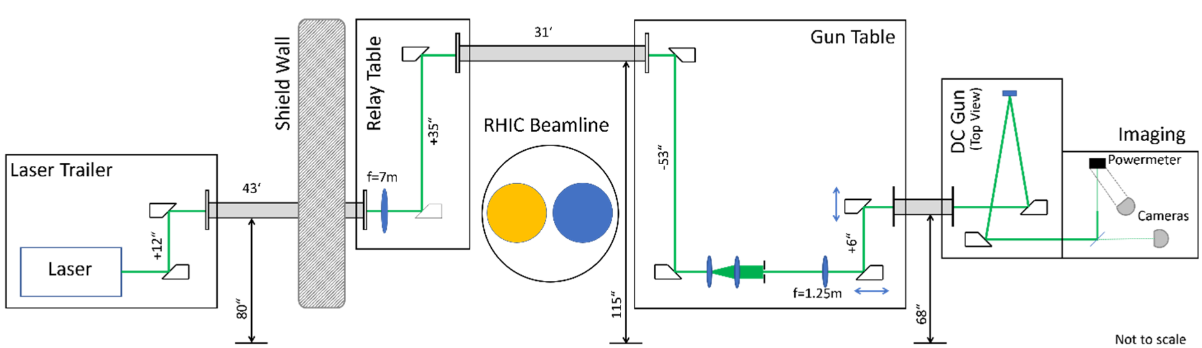

Figure 1: Schematic of the LEReC Laser Transport System.

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DESIGN CHALLENGES

The high peak power of the drive laser pulses (~2 kW) made a fiber optical transport impossible.

A trailer containing a laser room in this location had been used for a previous experiment and offered the shortest path with the least amount of bends to the LEReC DC gun.

However, vibration measurements on the optical table in the trailer showed vertical and horizontal motion unsuitable for a stable laser transport front end. This assessment motivated the mounting of the laser table on heavy steel blocks below ground, rather than on the trailer floor directly. Figure 2 shows a vibration measurement taken before the installation of the steel blocks.

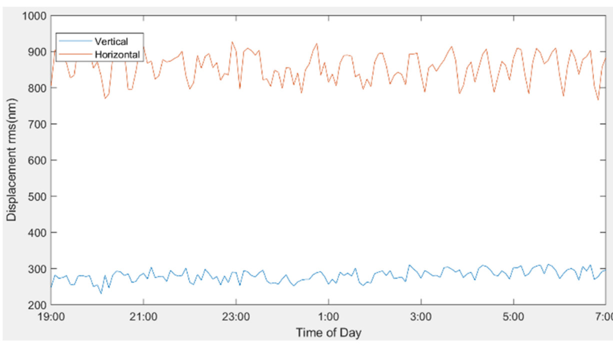

Figure 2: Overnight vibration measurement on the optical table surface in the trailer before the mounting of the table on the steel block below ground.

Another challenge was possible amplification of ground motion to the laser table surfaces inside the RHIC enclosure. The relay table had to be mounted 77 in above the floor level, the gun table 63 in.

To mitigate this and to prevent motion of the tables relative to each other and to the DC gun, they are rigidly attached to the building foundation by mounting them on solid concrete blocks that support the entire table footprint. Figure 3 shows a 3D rendering of the gun table.

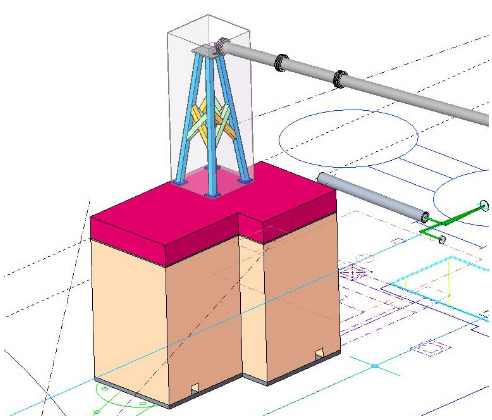

Figure 3: Rendering of the gun table, including incoming transport pipe and A-Frame to lower the incoming beam onto the table.

Specially designed A-Frames are used to support mirrors that lift and lower the laser beams on the individual tables. They are designed to be rigid with fundamental resonance frequencies well above 100 Hz. The goal of this construction was to minimize amplification as well as damping of any vibrations present in the floor that also affect the DC gun, which would lead to relative motion between tables and the DC gun.

To prevent coupling of vibrations of the transport tubes to the tables or to the beam motion, the tubes are free hanging and not rigidly attached to the table enclosures. The tubes are evacuated and kept below 1 mTorr to prevent refraction of the transported laser beam.

RESULTS

The installation of 40 tons of steel under the laser trailer on which to mount the optical table successfully reduced table surface vibrations by a factor of 7. Figure 4 shows a measurement taken after the installation of the steel blocks.

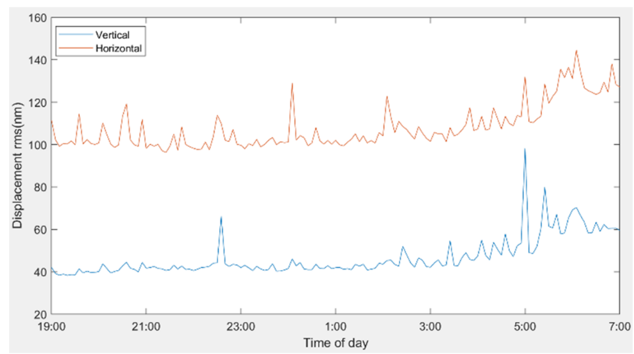

Figure 4: Overnight vibration measurements of the optical table surface after mounting of the table on steel blocks below ground. Anomalies in the measurements starting around 5:00 are due to work in the vicinity of the trailer.

Measurements of the position of an alignment laser at the gun table launched into the laser transport in the laser trailer show vibration levels within specifications. Figure 5 shows the rms measurement of the alignment laser spot position at the location of the aperture in vertical and horizontal directions.

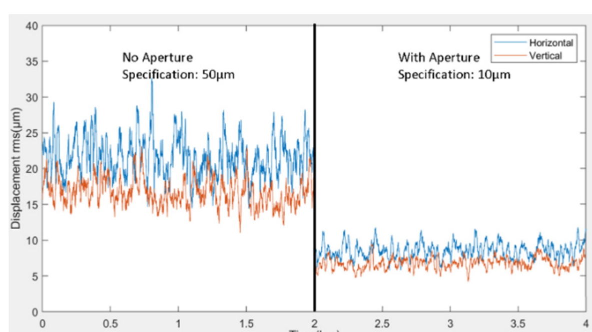

Figure 5: Measurement of the rms position of an alignment laser transported to the gun table at the location of the aperture that is imaged to the photocathode.

Figure 6 shows a 24-hour measurement of the alignment beam position on the gun table, capturing slow drifts due to changing weather conditions as well as day and night cycles.

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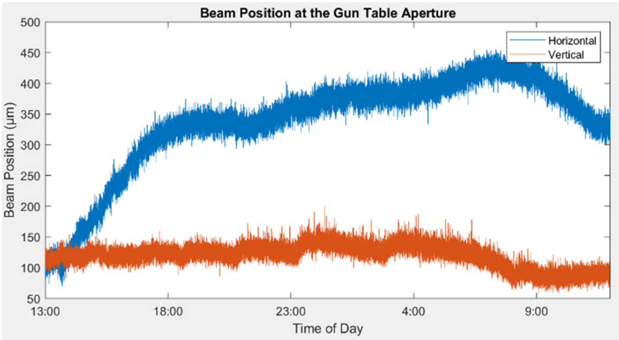

Figure 6: Measurement of an alignment beam position at the gun table over the course of a day relative to the centre of the camera sensor.

This weather-dependent motion motivated the installation of a slow, camera-based feedback system [4] that uses piezo-electric mirrors along the transport to adjust the alignment during operations.

SUMMARY

The Engineering solutions of mounting the optical table in the Trailer on steel blocks below ground, as well as attaching the transport tables rigidly to the foundation of the RHIC enclosure provide a quiet laser transport for LEReC.

The installation of a slow position feedback system to combat the weather and season related drifts of the transport produced good results in run19, successfully completing commissioning of the system.

ACKNOWLEDGEMENTS

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