Ground Motion Measurement

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TELSA's SC cavity has its main vibrational frequencies at 298 Hz and 460 Hz but since these resonace peaks are very narrow, they are easily distorted. Other vibrational sources in the 300 Hz to 500 Hz range can cause deformations in the SC cavity. These deformations lead to an alteration of the resonace frequency. The proposed site of the Energy Recovery Linac is in the midst of ground vibrating sources such as cars and civil traffic. Thus ground motion measurement was essential. Data taken exhibited noise frequencies in the area of the proposed ERL site.

I. INTRODUCTION

When electrons are accelerated, they emit synchrotron radiation in the form of x-rays tangential to the beam's orbit. This by-product of radiation supercedes the quality of any normal labatory x-ray source. In the next five years, an Energy Recovery Linac will replace CESR. The ERL will serve primarily as an x-ray source and can produce x-rays that supercede the best x-ray sources today in brightness, spatial resolution and time resolution by a factor of at least 100 due to narrower electron beams. As x-ray science grows so does the need for such a proficient x-ray source. In the ERL, electrons will be acclerated to 5 GeV using an electric field. The electric field oscillates at the resonance frequency of the superconducting cavity. When the electric field enters SC cavity, it is amplified and used to accelerate the electrons. However if the resonance frequency of the SC cavity is altered, the electric field will be out of sync with the resonance frequency of the SC cavity and the E field's amplification will be compromised. Since electron bunches are accelerated to several GeV, they use several 100mA currents. This requires that power in the order of GW be delivered to the beam. The Energy Recovery Linac recycles the energy used by electron bunches and uses it to accelerate a new batch of electrons. Thus energy is transferred from the electrons to the cavity then back to the new batch of elctrons. In order to do this, the cavities, which are continously filled with electric field energy, need to continously resonate. Superconducting cavities meet this requirement because they are able to resonate for long periods of times without dissipating energy[1]. However, superconducting cavities are very susceptible to mechanical vibrations. SC cavities have only a small range of frequencies that they can absorb without being distorted. When frequency excursions caused by mechanical vibrations exceed the bandwidth of the superconducting cavity, the SC cavity is slightly distorted[2]. This leads to a slightly different structure of the cavity, in which the resonance frequency is unknown. Haphazardly increasing the electric field to compensate for the lessened amplification is not feasible. Instead, measurements of ground vibaration in and on the Linac's trajectory was taken. With the data of such induced mechanical vibrations, accurate compensation of the electric field and/or proper insulation is made possible.

II. PROPOSED ERL SITE

The ERL site being analyzed at CESR ulitilizes the CESR ring, but also extends linearly farther down the road. Robert J. Kane Sports complex sits atop the ring of the ERL. This site exists amongst other athletic fields, a parking lot, nearby bus stops and automobile routes. The SC cavity of the ERL extends down Campus Road, in which another parking lot exists and more automobile and civil traffic is observed. At the end of the accelerator is a loop on the corner of Tower and Dryden Road. This intersection appears to be the most populated with cars, buses and trucks, though it is less civilly trafficked(Fig 1). As a result of the densely populated sources of mechanical vibrations, the ERL is likely to be affected in such an area. However, analysis of the induced ground vibrations and correlation with the SC cavity's consequent vibrations gives insight into this proposed problem.

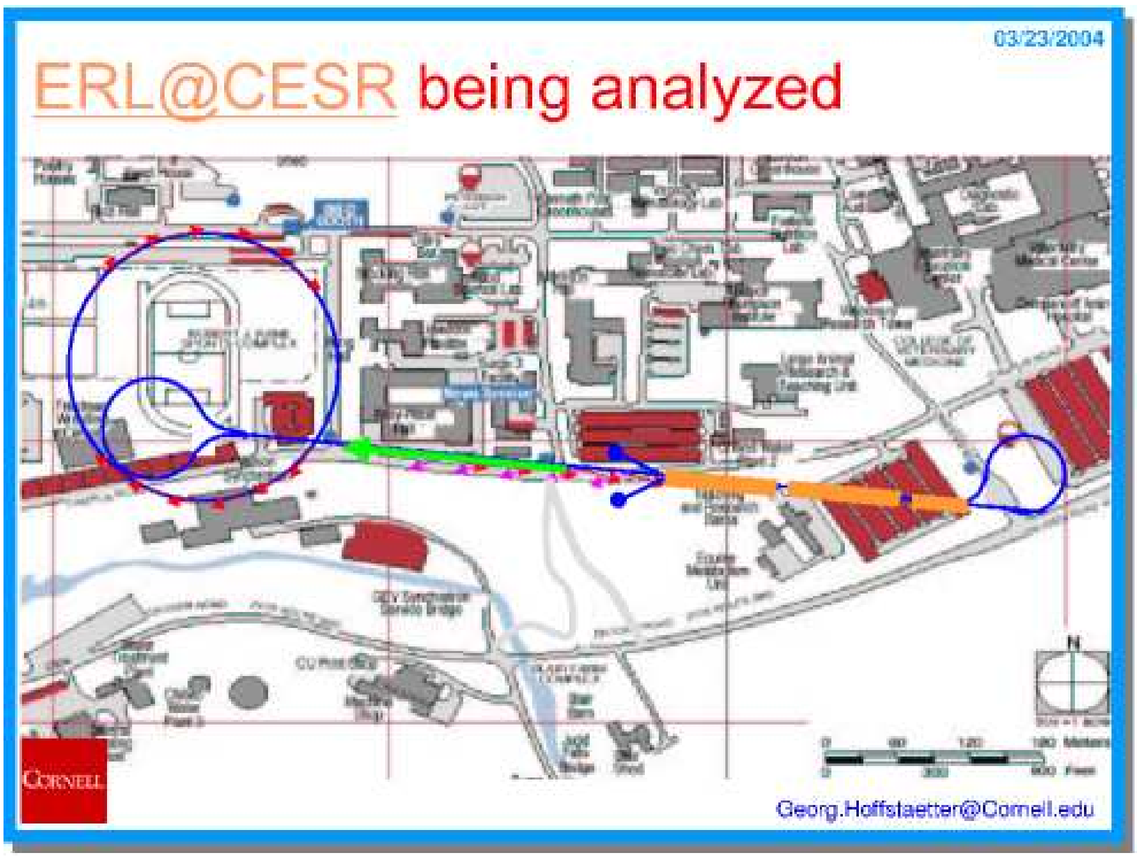

FIG. 1: Proposed ERL location

III. ACCELEROMETERS

Accelerometers were used to measure ground motion. In accelerometers, there is a crystal attached to a mass. When the ground vibrates, the mass is set into motion. The motion of the mass causes the ions in the crystal to seperate, thus inducing a voltage. This voltage is directly proportional to the force exerted by the mass. The force,in turn, is directly proportional to the accleration of the ground according to Newton's Law(**in-line**F=ma).

Two accelerometers with different sensitivities were compared. One of the accelerometers were sensitive well into the 1300 Hz range, while the other instrument was sensitive only up to 400 Hz. Ground motion analysis verified the differing sensitivities. On the ground in the CESR tunnel, both instruments agreed up to 400 Hz. Past this range, the least sensitive instrument gave signals of its own resonace frequencies (Fig 2) Measurements on the West cryostat demonstated another difference between the two accelerometers. With the most sensitive acceleromter, there were frequency peaks between 150 Hz and 200 Hz. There were also frequency peaks in the range of the cavity's resonances: 350 Hz, 400 Hz and between 450 Hz and 500 Hz (Fig 3). The acclerometer with the least sensitivity shared these same peaks, but exhibited more noise(Fig 4). Thus, the more sensitive accelerometer with the better noise floor was chosen to measure ground motion.

IV. GEOPHONES

Geophones were also used to measure the ground frequencies at certain places for a means of comparison. A simple diagram of the mechanics inside a geophone consists of a spring magnet system. When the ground vibrates, the spring causes a coil to move up and down across a magnet. This induces a current that is directly proportional to the voltage readout according to Ohm's Law (**in-line**V=IR).

V. CESR RING

Since CESR's ring will be ultilized by the ERL, measurements on the ground around the ring were taken to correlate with CESR's SC cavity vibration. On the corner of Campus Road and Wing Dr., fourier analysis reveals dominating frequencies at and below 200 HZ due to automobile and civil traffic. These peaks differed depending on varying degrees of traffic. There was a strong peak at half past the 10am hour at 400 Hz(Fig 5). Additional measurements taken further north on on Wing Dr.illustrated prominent low frequencies. In this area, there were no significant peaks near the SC cavity's resonance frequencies(Fig 6).

VI. CAMPUS ROAD

Measurements were taken at a possible location of the ERL's superconducting cavities. These measurements were then Fourier transformed to show prominent frequencies. The tail of the cavities exhibited random frequency amplitudes depending on the day and time from below 100Hz to around 150 Hz. These low frequencies were most likely cars, thus fluctuating depending on traffic density. Nevertheless, there were dominant peaks that prevailed, regardless of the amount of traffic, at slightly below and above 300 Hz(Fig 7). This is an area of concern since this frequency slightly mirrors the SC cavity's resonace frequency. Furthermore, measurements taken at the head of the SC cavity on Campus Road illustrated even higher frequency peaks below 100 Hz. This area is on the road and is more trafficked, yet this location gave no significant peaks around 300 Hz. Instead, there were some prevalent peaks around 500 Hz. The latter peaks are of concern because of the closeness it has to the SC cavity's resonance frequency(Fig 8). More measuremnts were taken on Campus Road and showed the same randomness of frequencies at and below 200 Hz. Only in the hour of 10am was there a dominant peak at 400Hz(Fig 9).

VII. TOWER & DRYDEN ROAD

The loop turn around at the end of the linear accelerator is on a heavily trafficked corner. The highest frequencies lie below 100 Hz. These low frequencies are likely due to automobile traffic. Still, despite date and time differences, there are frequencies that exist slightly below 300 Hz, at 300 Hz and between 300 and 350 Hz. Additionally, there are frequency peaks between 400 Hz and 500 Hz. These higher frequencies are more attention worthy because these are the frequencies that lie close to the resonance frequency of the SC cavity(Fig 10).

VIII. TUNNEL MEASUREMENTS

Vibrational frequencies were also measured in the CESR tunnel to correlate cavity vibration with ground vibration. Measurements on the ground in front of the West cryostat in the CESR tunnel revealed frequenciesin the vicinty of the cavity's resonating frequencies. These frequencies lie at 300 Hz, 350 Hz, bewtween 350 Hz and 400 Hz and at 450 Hz(Fig 11). Measurements on the West cryostat had these same dominant frequencies (Fig 3). Ground motion recorded in front of the East cryostat lacked frequencies in the range from 300 Hz to 500 Hz. Instead, there were strong peaks near 50 Hz and between 100 Hz and 150 Hz(Fig 12). East cryostat motion measurements shared these same frequencies, but also exhibited frequencies close to the superconducting cavity's resonance frequencies: below 300 Hz and below 400 Hz(Fig 13).

IX. RESULTS

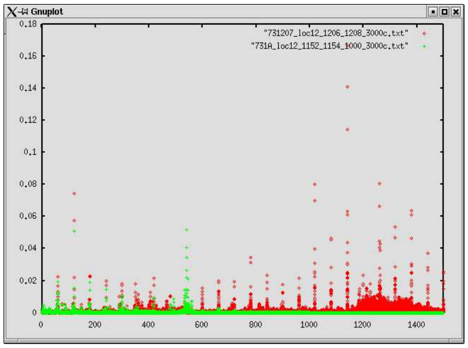

FIG. 2: Fourier Analysis of Ground Motion in CESR tunnel

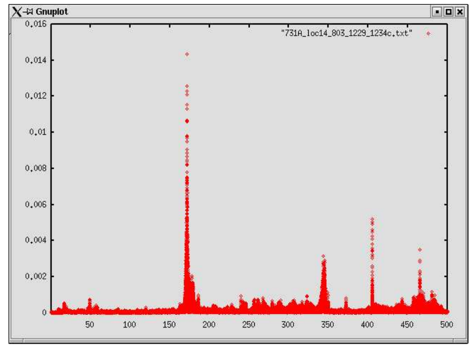

FIG. 3: Fourier Analysis of Cryostat Motion in CESR tunnel

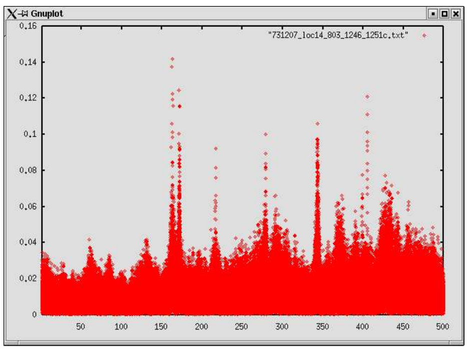

FIG. 4: Fourier Analysis of Cryostat Motion in CESR tunnel

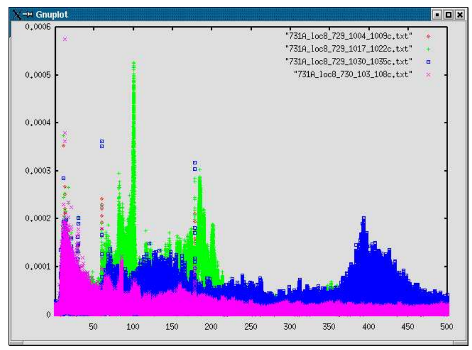

FIG. 5: Fourier Analysis of Ground Motion Frequencies at Wing Drive

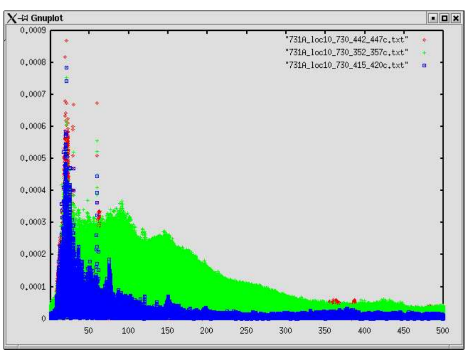

FIG. 6: Fourier Analysis of Ground Motion Frequencies at Wing Drive

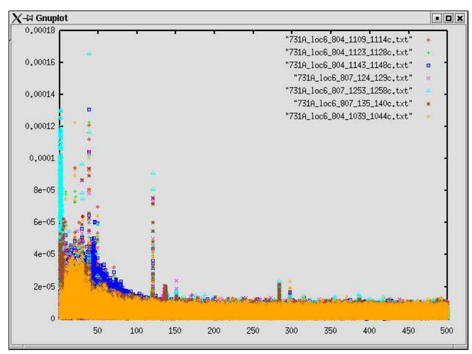

FIG. 7: Fourier Analysis of Ground Motion Frequencies at ERL SC Cavities

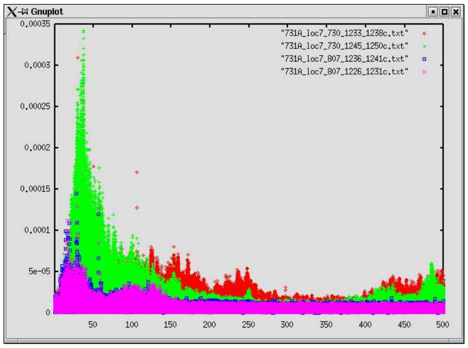

FIG. 8: Fourier Analysis of Ground Motion Frequencies at ERL SC Cavities

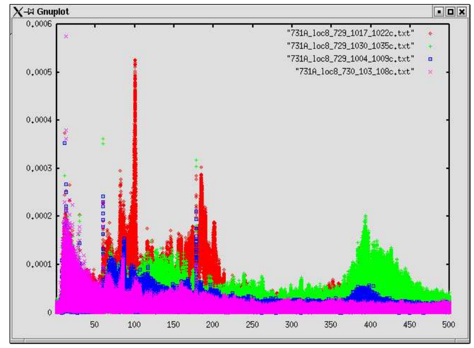

FIG. 9: Fourier Analysis of Ground Motion Frequencies on Campus Road

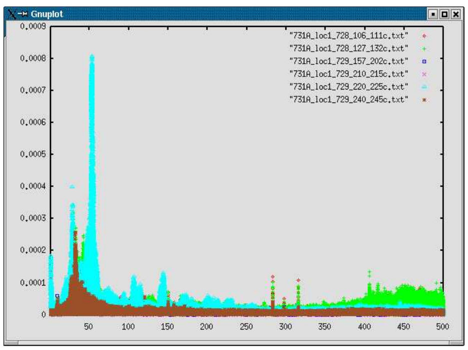

FIG. 10: Fourier Analysis of Ground Motion Frequencies at Turn Around Loop

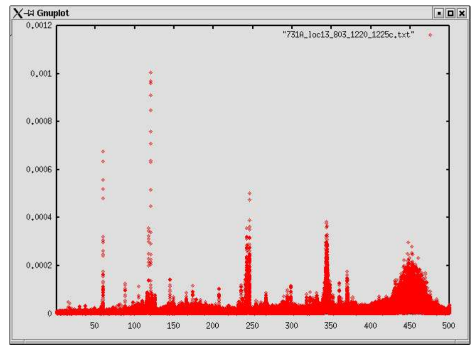

FIG. 11: Fourier Analysis of Ground Motion Frequencies near West Cryostat in CESR tunnel

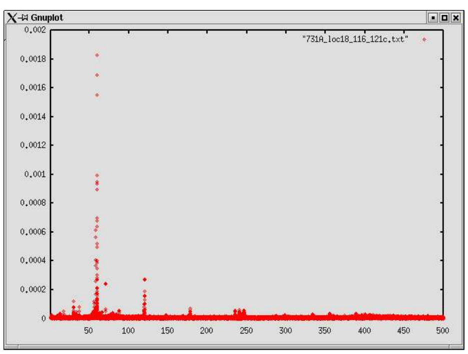

FIG. 12: Fourier Analysis of Ground Motion near East Cryostat in CESR tunnel

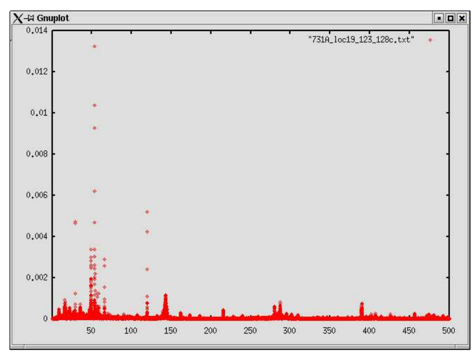

FIG. 13: Fourier Analysis of East Cryostat Motion in CESR tunnel

X. CONCLUSION

In the future ground motion, cryostat motion and cavity performance will be measured at Spallation Neutron Source in Tennessee and at the Rare Isotope Accelerator in Michigan. These measurements will be used to predict how well SC cavities for the ERL will perform at Cornell University. With this insight into ground, tunnel and cryostat vibrational frequencies, a comparison can be made with the locations in Tennessee and Michigan. Since superconducting caivities at Cornell will proceed those at SNS and Michigan State University, cavity performance can be formulated there against the ground and cryostat motion. With the ground and cryostat motion data at Cornell, it can be figured to how SC cavities may perform when they are implemented in the next five years.

XI. ACKNOWLEDGEMENTS

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[1] G.H. Hoffstaeter, I.V. Bazarov, D. Sagan, R. Talman, "A Lattice for a 5 GeV ERL in the CESR Tunnel", Report Cornell ERL-03-13, proc. PAC03.

[2] Stefan Simrock, Gevorg Petrosyan, Alberto Facco, Vladimir Zviagintsv, Stefan Andreoli, Rocco Paparella, "First Demonstration of Mocrophonic Control of a Superconducting Cavity with a Fast Piezoelectric Tuner", proc. of the Particle Accelerator Conference, 2003.

[3] "Ground Motion: Theory and Measurement", Zeroth-Order Design Report for the Next Linear Collider.