

Progress on bunch lengthening at the NSLS VUV ring*

R. Biscardi, W. Broome, S. Buda, J. Keane, G. Ramirez, J. Wachtel, J. M. Wang

National Synchrotron Light Source
Brookhaven National Laboratory
Upton, New York 11973

Abstract- This paper describes the basic theory and experimental results on bunch lengthening at the NSLS VUV ring. Emphasis will be placed on results of experiments conducted since the last report. A fourth harmonic cavity is used to provide the necessary conditions for bunch lengthening. Recent experiments have included using the harmonic cavity in a beam excited mode as well as using an external generator to provide the desired conditions.

force (RF voltage), the type of excitation (quantum emission) and other machine parameters. The stationary profile is shown to be²

$$\rho(\phi) = K_1 e^{-K_2 U(\phi)}$$

where

$$U(\phi) = K_3 \int_0^\phi [eV(\phi) - U(0)] d\phi$$

K_1, K_2 and K_3 are dependent upon other machine parameters.

Under normal operating conditions (small energy deviations, small phase oscillations) the potential function is quadratic and the longitudinal distribution is gaussian. With the addition of a fourth harmonic cavity, the potential function can be made quartic, leading to a trapezoidal shaped bunch. The dual cavity system produces a less dense bunch and longer Touschek lifetime.

The desired conditions to produce a quartic potential bucket have been calculated³. They require that the first and second derivatives of the total accelerating voltage equal zero, while the total voltage itself is such that the particles receive an energy gain equal to the radiative energy loss per turn (fig. 1).

1. Introduction

In the NSLS VUV ring, high current operation is inhibited by Touschek lifetime. A fourth harmonic cavity has been installed in the VUV ring to operate as a bunch lengthening cavity. By lengthening the stored bunch of electrons, the density is decreased. This decrease in density will improve the Touschek lifetime and thereby allow higher usable currents in the VUV ring.

Experiments¹ have been conducted which prove the feasibility of using a harmonic cavity to lengthen the bunch. However, these experiments were limited by a stainless steel structure which was prone to thermal runaway. An all copper cavity has been installed since these experiments to provide better heat transfer.

The initial tests performed with the new copper cavity in a beam excited mode were quite favorable and the system became operational. Attention was then turned to methods of optimizing the system. This requires an external generator to drive the harmonic cavity. The entire system must be held to tight amplitude and phase requirements. The details for such a system have not been worked out as of this date. However, the beam excited mode has been enhanced by a simple feedforward system in which the resonant frequency of the harmonic cavity is made proportional to beam current.

2. Theory

The longitudinal profile of a bunched beam in an electron storage ring is determined by the shape of the restoring

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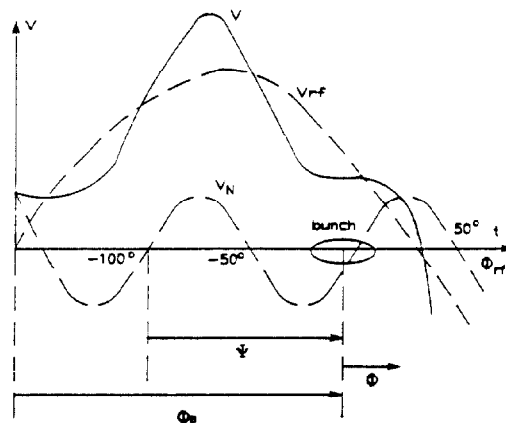


Fig. 1 Waveform with the double RF system.

To provide a true quartic potential for all beam currents, the harmonic cavity must be driven by an external generator. Tight tolerances on the required amplitude and phase must be maintained to produce an inflection point at the synchronous voltage. Using a passive system, these conditions may be approached by inductively detuning the harmonic cavity and allowing the beam alone to produce the harmonic cavity gap voltage. Although a true inflection point may never be reached, the bunch will be lengthened and lifetime improved.

3. Experimental results.

After the new cavity was installed, studies began using the harmonic cavity in the beam excited mode. The cavity was detuned inductively to 87 degrees. Bunch length was measured using a photodiode detector mounted at a synchrotron light port. After injecting to 900 mA, the harmonic cavity was brought closer to resonance.

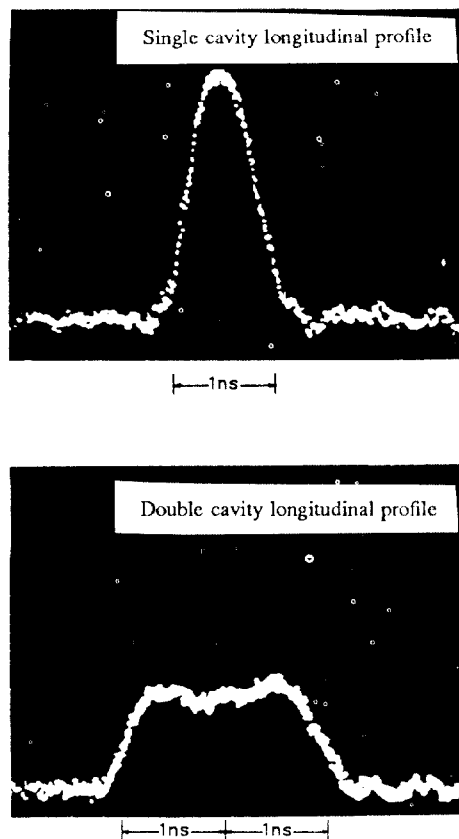


Fig. 2 Initial bunch length measurements.

As the cavity approached 84 degrees detuning the bunch began to lengthen. At 83 degrees detuning the bunch became trapezoidal in shape (Fig. 2). By this time the current had decayed to 700 mA, where the lifetime measured was improved by a factor of two over normal operating

conditions. At this point there were no problems with instabilities, and the current was allowed to decay to 500 mA where the harmonic cavity was moved closer to resonance. The bunch changed shape accordingly. Going from trapezoidal to double peaked. At approximately 78 degrees detuning the beam dumped.

The results of the first studies were very encouraging. Using a passive cavity, a stored bunch of electrons was lengthened. Typical lifetime was improved from a factor of two at currents greater than 600 mA to a factor of 1.5 at currents greater than 400 mA. Typical current vs. time profiles are as shown in figure 3. Calculations of the induced voltage in the harmonic cavity at these detuning angles produced numbers around 20 KV. This is close to the voltage required for optimum bunch lengthening. The system went into operation with a fixed detuning angle of 83 degrees.

Two important observations were made during the studies. One being the irregular bunch profile of different bunches within a fill (fig. 4). The other being a jump in phase of the bunch just before beam dumped at 78 degrees detuning. Continuing studies were done to look for the causes of these observations.

The irregular bunch profile was attributed to either: 1) interaction with the longitudinal feedback system or 2) to a higher order mode other than the 211 MHz cavity. Disconnecting the longitudinal feedback system during a fill showed no change in longitudinal profile, thus, removing it as a suspected cause.

The initial studies were done with an asymmetric fill (7 out of 9 bunches filled). When a symmetric three bunch fill was used, the profile of the 3 bunches were nearly identical. Therefore, it is believed that the cause of the irregular bunch profiles is a higher order mode which is driven by a rotation harmonic of the beam and is not an RF harmonic. A mode at an RF harmonic with high Q would act on each bunch in the same manner. Sweeps of the cavities showed a mode in the harmonic cavity at 270 MHz. This mode does lie on a rotation harmonic and is considered the probable cause of irregular bunch pattern. Plans are being made to damp this mode

Careful examination of the longitudinal profile of the bunch as the cavity was moved towards resonance showed the bunch jumping between two longitudinal phase locations. The rate at which the transition between the two states occurred increased in frequency as the cavity was moved closer to resonance until beam dumped as mentioned above. The cause of this motion is not fully understood, and work is continuing to understand the mechanism for this motion.

4. Feedforward

A simple system to provide better operation of the passive system has been implemented. It involves changing the resonant frequency of the cavity proportional to beam current. A beam current signal is taken from a stripline pickup. This signal is filtered, detected, and scaled to drive a

temperature controller. By changing the temperature of the harmonic cavity, its resonant frequency is changed. This system allows higher current to be stored in the ring while still providing lifetime improvement at lower currents. This is achieved by increasing the magnitude of the cavity impedance as the beam current decreases, keeping the magnitude of the gap voltage in the harmonic cavity relatively constant.

5. Summary

The bunch lengthening cavity is operational in the NSLS VUV ring in a passive mode. A feedforward system is used to enhance its operation. Lifetime improvements range from a factor of two at high currents to a factor of 1.5 at lower currents. Work is continuing on implementation of a generator system as well as on understanding observations made during studies.

6. Acknowledgements

The authors acknowledge the technical excellence of Jeffrey Aspenleiter during the fabrication and installation of the harmonic cavity.

7. References

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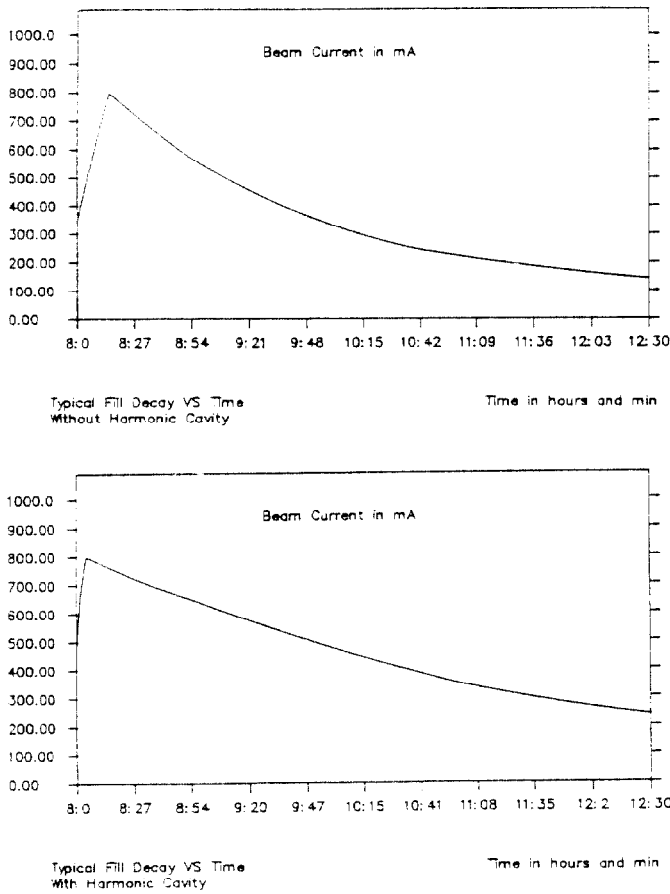


Fig. 3 Typical current decay

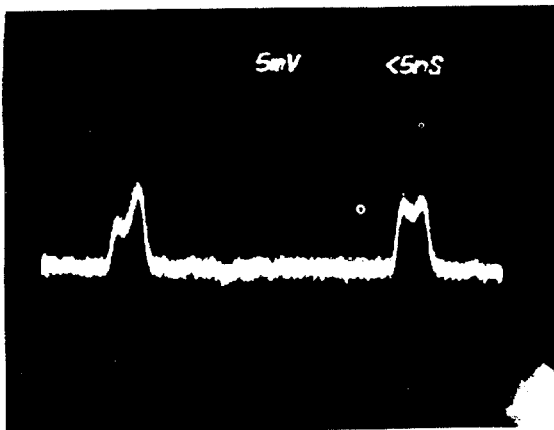


Fig. 4 Two bunches of a seven bunch fill