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Progress in Commissioning the Very High Frequency (VHF) Cavity

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Subject Progress in Commissioning the Very High Frequency (VHF) Cavity

Introduction

A Very High Frequency (VHF) rf cavity has been installed in the G-20 straight section in the AGS ring. This rf structure operates in the range of the 20th harmonic of the AGS accelerating rf frequency. Details of the physical design of the cavity and an overview of the justification and first operating results can be found in References 1-4. A brief statement as to the need for such an addition to the AGS is that as the beam presently passes through transition, the resulting phase mismatch due to space charge leads to uncontrolled bunch dilution and longitudinal emittance growth. The action of the VHF cavity is to reduce the line charge density of the beam (dilute) in a controlled manner such that the effective space charge forces are also reduced. Therefore, the beam should pass through transition in a predictable and reproducible fashion and with less beam lost in the process.

Procedure

In order to power the VHF cavity, the beam revolution frequency and thus the main magnet field must be nearly constant. This requires that in addition to an extraction flattop, there be an early dilution flat porch of approximately 100 ms in the cycle. During the early test periods, the stability of the dilution porch was unacceptable in that large (± 3 kHz) variations in the rf acceleration frequency were noted due to cycle-to-cycle differences in the main guide field on that porch.[5] As a result, new control circuits were designed and installed to provide the same feedback loops for the early porch that were available for the extraction flattop. The stability of the VHF dilution porch is now ± 0.14 Gauss (or in terms of the accelerating rf frequency at 1.5 GeV, ± 100 Hz).

A parameter list used in the studies is given in Table I. Results are in Table II and are from a study focused on the best dilution at a given phase modulation program. For this study, the program ramped the modulation frequency in sawtooth fashion. In an attempt to better understand the dilution parameters, a much simpler modulation program, namely, holding the modulation frequency fixed, was tried. The results are summarized in Figure 2 for dilution lasting a constant time.

Observations and Results

Early work was done during a period of very low intensity in the AGS ($\approx 5 \times 10^{10}$ protons/pulse). However, when later high intensity ($\approx 1.0 \times 10^{13}$) studies were conducted, within the ability to quantify the results, there was no beam intensity dependence in the amount or rate of beam dilution achieved by powering the VHF cavity.

TABLE I

Operating Parameters

f_{vhf}/f_{rf}	22-1/2
Cavity Frequency	93.152 MHz
Cavity Voltage	20 kV
Main RF Accelerating Voltage	165-220 kV
Main RF Accelerating Frequency	4.14 MHz
Dilution Period	80 ms
Frequency of Phase Modulation	6.0-7.0 kHz
Phase Modulation Sweep Period	4 ms
Phase Deviation	$\pm \pi$

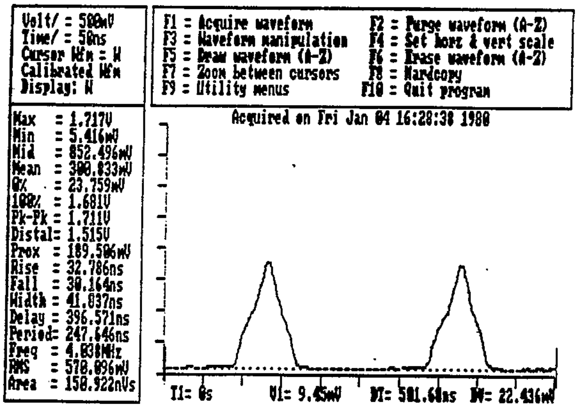
The results noted in Table II below were obtained by setting the operating conditions as close as possible to those provided by the theoretical model provided by J. Kats. In both this and later work there is evidence to suggest these parameters do indeed permit the most efficient dilution in the AGS. Further exploration of the effects of the various parameters involved in this process must be conducted prior to concluding that the VHF cavity dilution process is phenomenologically well understood. Further work on diagnostic signals, the documentation of these and of the specific procedure to be followed for standard dilution is necessary before the VHF cavity dilution system can be declared to be an operational part of the AGS facility.

TABLE II
Beam Measurements

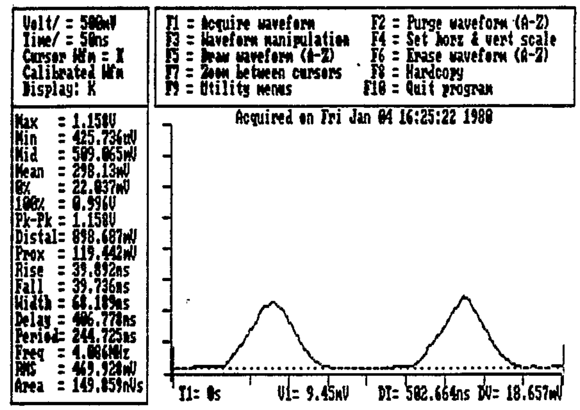
AGS Beam Intensity	1×10^{13} protons/ pulse
Main RF Accelerating Voltage	220 kV
Main RF Bucket Area	4.11 eV-s
Bunch Length at Time TP3	80 ± 5 ns
Bunch Length at Time TP5	110 ± 5 ns
Bunch Area at Time TP3	0.82 ± 0.1 eV-s
Bunch Area at Time TP5	1.47 ± 0.1 eV-s
Main RF Accelerating Voltage	165 kV
Main RF Bucket Area	3.57 eV-s
Bunch Length at Time TP3	80 ± 5 ns
Bunch Length at Time TP5	135 ± 5 ns
Bunch Area at Time TP3	0.71 ± 0.1 eV-s
Bunch Area at Time TP5	1.81 ± 0.1 eV-s

The above beam measurements indicate a fairly significant dependence upon the ratio of the V_{rf} to V_{vhf} and will be subject to later investigation. However, one desired result is that the tails of the bunch not become too large in the process of dilution. In the above data, it was found that while the peak particle density decreased more rapidly during dilution at lower V_{rf}, the tails also became less well defined. There may have to be some compromise to the voltage ratio if this cannot be improved by other means.

The following Figure 1 shows a typical bunch in the AGS just prior to and immediately after powering the VHF cavity. The exact definition of "best dilution" has not yet been obtained because it encompasses both the increase in longitudinal extent and the decrease in peak particle density. In addition, the exact nature of the particle distribution within the bunch for most efficient dilution must be defined. Eventually, the AGS itself as always will provide the answers by tracking the bunch history through the dilution process and through transition.



Bunch prior to dilution.



Bunch after dilution.

Figure 1.

In Figure 2, results from powering the VHF cavity with a series of fixed frequency phase modulation programs are given. The modulation frequency is the independent variable. The length of the dilution period is held fixed (40 ms). Two measures of dilution are plotted; that of fractional bunch length increase and bunch height decrease. There are theoretical suggestions that these plots should be (1) frequency independent (i.e., flat) or (2) have strong oscillating behavior. Also plotted (since this is a study note) are two reductions of the data implying the difficulty to extract these fractional changes from the pictures. In fact, in the immediate vicinity of 6 kHz, the character of dilution seemed strongly frequency dependent but that data is not plotted because the necessary photos were not taken.

As the error bars indicate, to measure the length change is much more difficult than to measure the height change. Both measures assume the density distribution is matched to the bucket contours, i.e., that bunch height and width do not change over a synchrotron oscillation. This is only approximately true. Trying out techniques to refine these measures is a major goal of the next study.

Although the data do not yet confirm it, one very interesting hypothesis would be that the evolution of bunch height reduction and bunch length increase during dilution may not be totally correlated. Then the setup yielding the greatest height reduction for a given length increase would be very interesting since a subsequent reduction in bucket area (when we return to acceleration) would be less likely to cause beam loss.

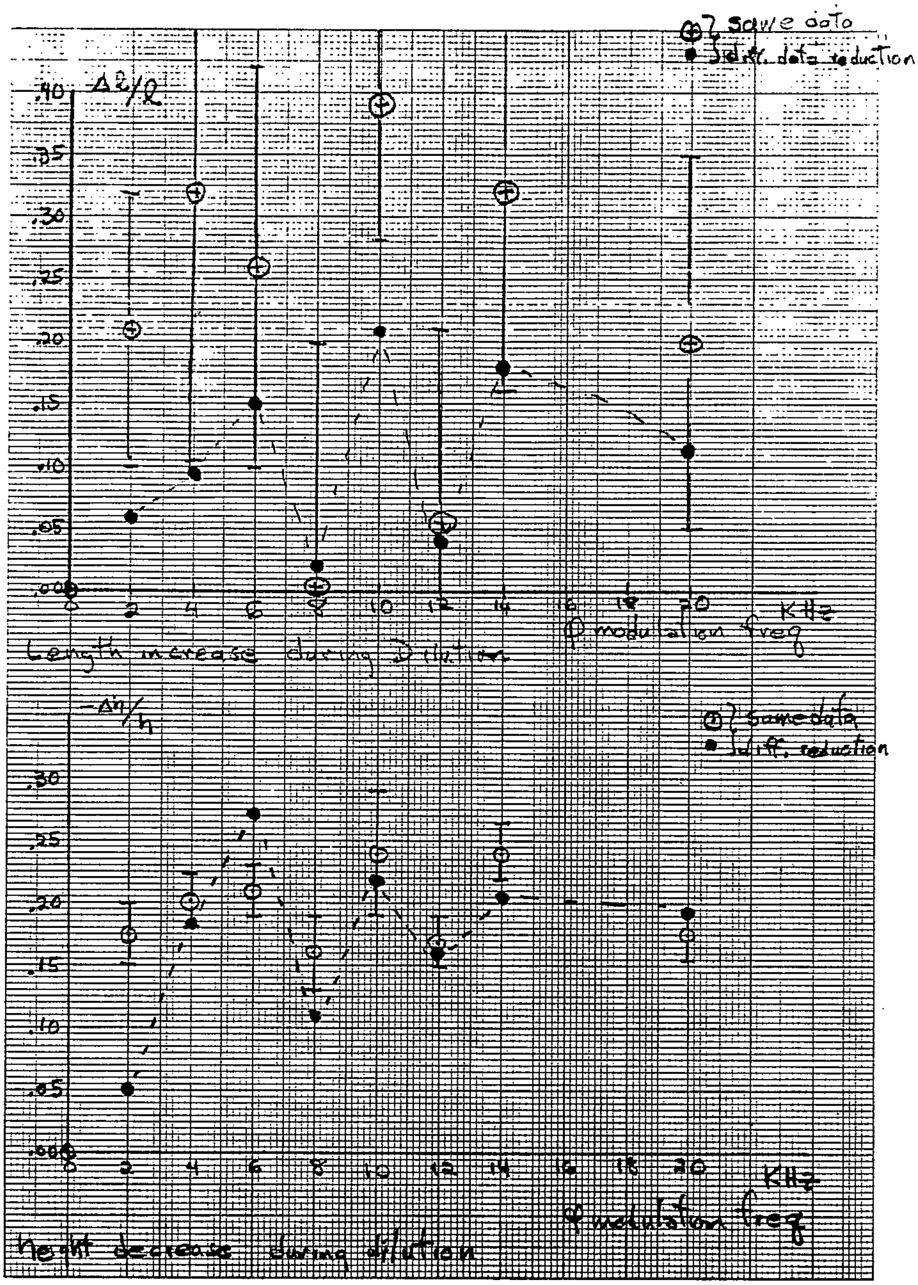


Figure 2.

References

1. J.M. Kats, IEEE Particle Accelerator Conf., 1281, 1987.
2. J.M. Brennan, et al., A High Harmonic Cavity for Controlled Longitudinal Phase Space Dilution in the AGS, EPAC, Rome, 1988.
3. R.K. Reece, AGS/AD/Op. Note No. 23.
4. R.K. Reece, et al., Operational Experience and Techniques for Controlled Longitudinal Phase Space Dilution in the AGS Using a High Harmonic Cavity, 1989 IEEE Particle Accelerator Conf., to be published.
5. J.M. Brennan, AGS Studies Report No. 236.