# RK-TBA STUDIES IN KA-BAND

S.M. Lidia, S.S. Yu
E.O. Lawrence Berkeley National Laboratory, Berkeley, California 94720, USA

J. Gardelle, T. Lefevre, J.L. Rullier
CEA/Centre d'Etudes Scientifiques et Techniques d'Aquitaine, BP 2, 33114 Le Barp, France

G.A. Westenskow
Lawrence Livermore National Laboratory, Livermore, California 94551, USA

J.T. Donohue
Centre d'Etudes Nucleaires de Bordeaux-Gradignan, BP 120, 33175 Gradignan, France

*Abstract*

It is well established that operating frequencies in the 30-GHz range and higher are required to obtain the high accelerating gradients needed by linear collider systems that wish to probe center-of-mass energies significantly higher than 1 TeV. As an rf power source for high-energy linear colliders, relativistic klystron two-beam accelerators (RK-TBAs) have been shown theoretically to scale favorably to frequencies higher than X-band. To complement our studies of RK-TBA systems at 11.424 GHz, we are undertaking experimental tests of components at both 35 and 30 GHz. These studies will be conducted at the CEA/CESTA facility using the LELIA and PIVAIR electron linear induction accelerators (LIAs), respectively, and will concentrate on the interaction of the intense, modulated electron beams with rf cavity structures, compact induction modules, and permanent magnet quadrupole transport lattices. Details of the rf cavity design and the proposed experiments are discussed.

## 1 INTRODUCTION

To explore center-of-mass energies in the multi-TeV range with electron-positron linear colliders will require accelerating gradients of several hundred MeV per meter. Scaling of conventional, copper-based structure technology shows that this can be considered at operating frequencies around 30 GHz (Ka band) [1]. Among the myriad ways of producing pulsed, high-power microwaves to drive accelerating structures, RK-TBA technology has been shown theoretically to be one of the most efficient [2]. As a testbed for RK-TBA physics and engineering studies, the 11.4-GHz prototype RTA is currently being commissioned [3]. To complement these studies, we will conduct tests of rf output structures and bunched beam transport at 30-35 GHz. This work is conducted through a collaboration of LBNL personnel with groups at CEA/CESTA and CERN. This paper discusses these upcoming experiments, with emphasis on rf cavity design and measurements of longitudinal bunching.

## 2 TESTS ON LELIA

Since 1995, the induction linac LELIA at the CEA/CESTA facility has been used to produce a 2-MeV, 800-A, 60-ns beam modulated at 35 GHz by a free-electron laser. This work has been conducted with support of CERN to study the generation of a suitable drive beam to power CLIC Transfer Structures (CTS). Of equal interest is the possibility of using the modulated beam to drive inductively detuned rf structures in an RK-TBA. In this case, the rf properties of the cavities determine the longitudinal beam dynamics. Hence, measurements of longitudinal phase space bunching are important to make. Diagnostics techniques developed at CESTA have, for the first time, enabled us to directly view the electron bunching, and to capture the image with a streak camera [4,5].

### *2.1 Inductively Detuned SW RF Cavities*

The first set of experiments will study the interaction of the modulated beam with standing wave rf cavities. Three different cavities are to be constructed and studied sequentially, one idler and two single-output cavities. We have modeled these structures with the Superfish, URMEL-T, and GdfidL codes [6]. The characteristics of the cavities are listed in Table 1.

| | Idler | Low Q | High Q |
|---|---|---|---|
| f [GHz] | 34-36 | 35 | 35 |
| Q | 363 | 6 | 45 |
| R/Q [Ω] | 45 | 45 | 45 |
| $P_{out}$ [MW] | - | 0.7 | 5.0 |
| $E_{peak}$ [MV/m] | 400 | 7 | 50 |

Table 1. Parameters of rf cavities.

The idler cavity has been designed to accept variable-radius 'tuning rings' in the inner pillbox region. These rings adjust the inner radius of the cavity to permit tuning the fundamental mode frequency over the range 34-36 GHz. The frequency of the cavity can be adjusted so that the longitudinal impedance seen by he beam is resonant, or detuned (capacitively/inductively). The idler cavity assembly is shown in Figure 2.

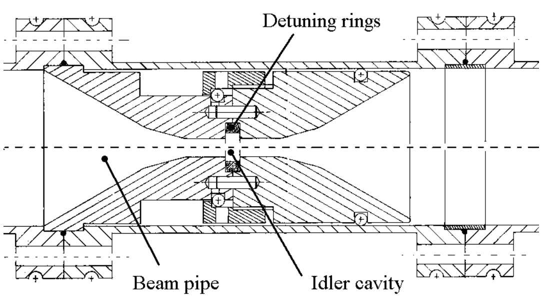


Figure 2. Idler cavity assembly.

The tuning rings will be manufactured by wrapping a layer of stainless steel (304SS) around a narrow spool that exhibits a slight taper. Individual rings will then be cut from this spool. This permits an accurate measure of the ring's inner radius, as well as differences in the radii between different rings.

The output cavities are designed with only a single output port. This port is attached to a connecting waveguide which is expanded to mate with standard WR-28 guide. Figure 3 shows a quarter of the geometry.

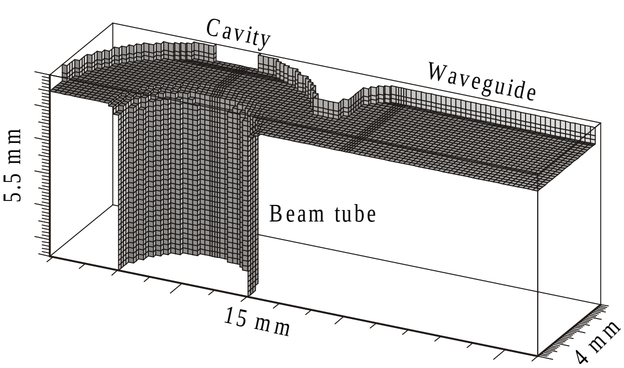


Figure 3. Output cavity quarter-geometry. The beam travels vertically through the beam tube.

This single output port can introduce an unwanted transverse impulse to the beam as it traverses the structure. The pillbox region of the cavity has been designed slightly off-center from the beamline axis to compensate for this. As a result, the linear variation of the longitudinal electric field has been strongly suppressed. A small quadratic variation is still present. However, any quadrupole interaction is slight. A cross-section of the longitudinal electric field distribution in the cavity midplane normal to the beam axis is shown in Figure 4.

The expected performance of these cavities is listed in Table 1. As can be seen, only a modest amount of output power is expected from these structures. These first experiments will concentrate mostly on beam dynamics issues: generation and transport of an intense, modulated beam through a narrow aperture cavity; and observation of the interaction of the cavity upon the beam. Later experiments may involve more sophisticated cavity designs, intended to produce rf output levels sufficiently high to drive accelerating structures.

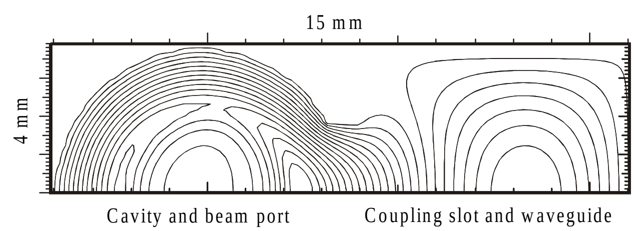


Figure 4. Cross-section of output cavity showing symmetrization of the modal longitudinal electric field.

## *2.2 Longitudinal Beam Dynamics Studies*

Optical measurements will be performed to study the time-dependent beam-cavity interaction. Bunches will be extracted, and their longitudinal bunching characteristics measured. This allows us to make a comparison between our simulation codes and experiment. The primary measurement will be of the bunching parameter of the beam before and after it exits the cavity region. This will be compared with measurements of bunching when the beam is freely propagating. Simulation results of the evolution of the bunching parameter along the beamline following the FEL are shown in Figure 5. The cavity is located 28.5 cm from the end of the FEL. Measurements will also be made of the relative phase of the output rf power with respect to the FEL output.

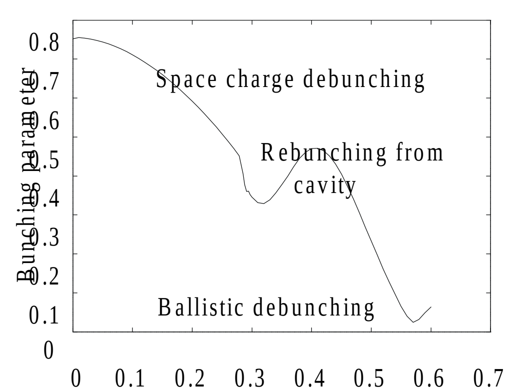


Figure 5. Evolution of the bunching parameter from the end of the FEL through the cavity.

## 2.3 Observation Of Bunching Characteristics

An optical diagnostic based on Cerenkov emission will be used to measure the bunching characteristics. The beam is stopped by a movable, fused-silica target. A gated CCD camera and a fast streak camera (2-ps resolution) will be used to collect and analyze a small part of the visible Cerenkov light. Figure 6 shows an example of the streak camera output, clearly displaying the bunching.

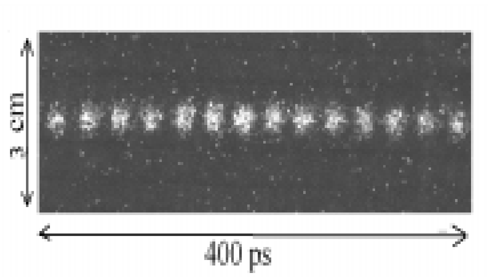


Figure. 6. Streak images of 35GHz bunches.

# 3 TESTS ON PIVAIR

The PIVAIR induction linac generates a nominal 7.2-MeV, 3-kA, 60-ns beam. These values make it very attractive as an injector for a 30-GHz RK-TBA system to power a multi-TeV linear collider. A preliminary point design for a multi-TeV-scale linear collider system using an RK-TBA driver and operating at 30 GHz has already been presented [7]. The RK-TBA drive beam architecture is shown in Figure 7.

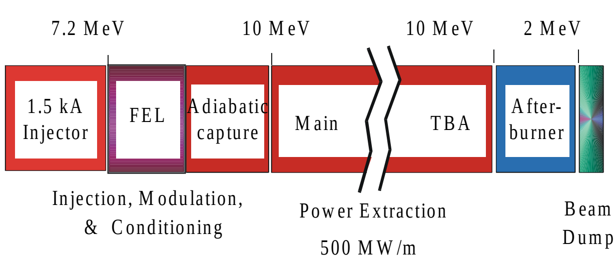


Figure 7. 30-GHz RKTBA architecture.

The front end of the drive beam injector for the Main TBA is composed of an electron gun and accelerator ('Injector'), a free electron laser ('FEL') to provide the modulation, and an 'Adiabatic capture' section to provide for bunch compression, additional acceleration, and other pulse conditioning. This latter effect may include shaping of the front-end current profile to provide a ramped current pulse. Power extraction and reacceleration then occurs in the Main TBA section.

A current proposal [8] seeks to use PIVAIR for TBA-related studies. An FEL to provide 30GHz modulation is to be constructed, followed by a beamline to support TBA studies. PIVAIR operated as a test stand thus will provide a valuable resource in the effort to examine beam dynamics and to test designs of beamline components for a high frequency RK-TBA. Of particular concern are the rf output structures and induction modules in the Main TBA section. Prototypes may be designed and then tested on the PIVAIR beamline, once a modulated beam is present.

# 4 CONCLUSIONS

Current experiments are studying the beam-cavity interaction in RK-TBAs at frequencies around 30GHz, ostensibly extending the utility of RK-TBA power sources to higher frequencies and to higher peak output power levels. These studies will enable us to more accurately predict and model beam dynamics in a large scale driver for a multi-TeV electron-positron linear collider.

# 5 ACKNOWLEDGMENTS

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