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CONVENTIONAL POWER SOURCES FOR COLLIDERS*

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ABSTRACT

At SLAC we are developing high peak-power klystrons to explore the limits of use of conventional power sources in future linear colliders. In an experimental tube we have achieved 150 MW at 1 μsec pulse width at 2856 MHz. In production tubes for SLAC Linear Collider (SLC) we routinely achieve 67 MW at 3.5 μsec pulse width and 180 pps. Over 200 of the klystrons are in routine operation in SLC. An experimental klystron at 8.568 GHz is presently under construction with a design objective of 30 MW at 1 μsec. A program is starting on the relativistic klystron whose performance will be analyzed in the exploration of the limits of klystrons at very short pulse widths.

1. Introduction

A colliding linear accelerator is being considered for the Stanford Linear Accelerator Center (SLAC). It is likely that a proposal will be written in 1990 for construction of a 0.5 - 1 TeV c.m. collider. This Large Linear Collider (LLC) will consist of several critical items, one of which is the type of power source. Early conceptual designs suggest linacs of 3 km in length and for 0.5 TeV this requires gradients of 166 MeV/m. From total power considerations, higher frequencies than the SLAC frequency (2.856 GHz) are preferred and designs have been suggested at frequencies of four times SLAC frequency and higher. Peak power requirements then are in excess of 500 MW/meter. No conventional power sources exist which can supply this power in units which could energize one meter or more of the proposed accelerators. The SLAC Linear Collider (SLC) presently being commissioned is successfully employing over 200 klystrons to accelerate a stable beam meeting SLC specifications to over 50 GeV. [1] These klystrons produce over 65 MW each in 3.5 μsec pulses and use RF pulse compression to reach about 200 MW peak power over a 1 μsec. Also in an experimental tube 150 MW has been achieved in 1 μsec pulse widths. Thus klystrons are a potential candidate for LLC power sources. A scaling of existing klystrons suggests that 100 MW peak power at 10 GHz is possible with a pulse width of 2 μsec. To explore this power range a research and development program is underway at SLAC. The first stage of that program is a 30 MW peak power klystron at X-Band. If it turns out that 100 MW tube is feasible, it might be possible to compress the 2μsec RF pulse to produce a peak power in excess of 500 MW. This pulse compression requires the development of low-loss delay lines which are cumbersome, expensive and suffer mode coupling problems of a very formidable nature. Thus another approach is

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needed. One way would be to compress the energy pulse before the RF is generated. The performance of the klystron type interaction at very short pulse widths has not been explored but there are reasons to believe that much higher peak power is attainable as the pulse width decreases. Single bunch linear colliders at X-Band require peak powers of 500 MW/meter but only for about 50 ns per pulse. If pulses of adequate quality (fast-rise time, good flat top) can be produced, the scaling laws for long pulse (> 1μsec) will not apply. Previous breakdown studies suggest that high electric fields can be maintained for nanosecond pulses. If these pulses can be maintained, then the response time of the klystrons to short pulses becomes important and requires study.

2. Short Pulse Production

In modulators for microsecond pulse tubes, compression is done by using pulse forming networks consisting of delay lines formed from an array of capacitors and chokes. Recently, at the Lawrence Livermore Laboratories new ferro-magnetic metallic glass materials have been used to produce pulse compression. [2] This is a high-efficiency method which produces fast rise-time pulses in the tens of nanosecond range. These have been applied successfully in induction linear accelerators to produce MV/kA beams. This technique makes feasible the production of short-pulse beams for klystron interactions. These beams would be in excess of 1 MV and if properly bunched and made to interact with extraction cavities, very high peak RF power would be produced. This describes relativistic klystron amplifiers (RKA).

3. Relativistic Klystrons

There exists in Lawrence Livermore National Laboratory (LLNL) an ongoing program in induction linear accelerators producing and accelerating high voltage (> 1 MeV) and high current (> 1 kA) short pulse (<100 ns) electron beams. Some of this work is also being done in collaboration with Lawrence Berkeley Laboratories (LBL). At SLAC there is an ongoing program of development of high peak power klystrons at up to the 10 GHz range of frequencies. Since the three laboratories are interested in RF power sources for high gradient linacs, a collaborative program has been started between the laboratories. This program is discussed in the Workshop by Simon Yu. [3] A variety of high voltage, high current beams produced by induction acceleration and bunched by velocity modulation or other means and using RF extraction cavities are being explored to produce the necessary gigawatts of RF power for LLC.

The program has three main approaches. They are:

a. The production of a 1 MV, 1 kA short pulse beam by magnetic compression in a conventional klystron amplifier and extraction from this 1 GW beam of at least 50% of the power at RF frequency. This would give in excess of 500 MW peak power from a single unit.

b. In a small induction linear accelerator the production, bunching and acceleration of a 10 GW beam. This beam could be nominally 5 MeV and 2 kA. This beam would drift through a series of RF extraction cavities with each of them extracting 1 GW of RF power. This module would energize 10 meters of LLC in a single unit.

c. In true two beam accelerator [4] an induction linear accelerator would accelerate nominally 20 kA of beam up to 50 MeV for a 1 TW beam and by using a series of RF extraction cavities 1 GW would be extracted from each cavity. This would energize 1 km of LLC in a single unit.

The feasibilities of all three approaches are being studied and experiments are being planned utilizing induction accelerators in operation at LLNL.

4. Conclusion

Prospects for using some derivative of a relativistic klystron in large linear colliders look promising and are being explored.

This report to the Workshop is a brief summary of work in progress. There are a large number of people contributing to this SLAC/LLNL/LBL collaboration and their work will be reported in the appropriate manner in the future.

5. References

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