Stability improvement of high power klystron YK1303

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ABSTRACT

High efficiency klystrons tend to show instabilities at or near saturation due to backstreaming electrons from output region. This effect can cause sideband oscillation on RF output signal and anode current spikes at modulating anode. In storage ring RF systems this behavior is a severe problem and may lead to beam loss.

In this paper an instability simulation is given together with practical measurements. Also preventive measures are presented for high power klystron YK1303.

1. INTRODUCTION

When operating high efficient power klystrons into a mismatched load, one can observe sideband oscillations on output signal along with an irregular increase in modulating anode current. The appearance of instabilities is influenced also by magnetic field and input power level. This sideband oscillation can be measured by a spectrum analyzer coupled to the output signal and shows power levels up to 20 dB below main signal for a 1 MW klystron YK1303. Also modulating anode current increases to levels reaching the power supply pretended maximum of about 5 mA. This high current may interrupt operation when exceeding the safety interlock level or lead to drops in output power in case of high ohmic anode power supplies. In some klystrons the stability range decreased by time and they became unstable even under matched operation after about 3000 h [1].

2. INSTABILITY ANALYSIS

Some efforts were made in theory and practical measurements to understand the origin of these instabilities. When tuning an instability dependant parameter like main focus field out of the stable region one can normally observe first a noisy increase in modulating anode current leading to the sudden appearance of more or less stable sideband oscillations in RF output signal. A stable sideband oscillation causes also a stable anode current. The frequencies of such spurious signals are symmetric to the input frequency indicating an AM-modulation. The frequency of the upper sideband is often correlated to one of the buncher cavities. Because of the very high Q_0 of the buncher cavities these discrete frequencies are favoured for self oscillation. In order to examine the influence of a mismatched load we inserted a reflecting teflon plate into the waveguide between klystron and matched water load choosing it´s thickness to produce a VSWR of 1.2. By moving the plate in the waveguide one can change the phase angle of this mismatch. The measured instability behaviour together

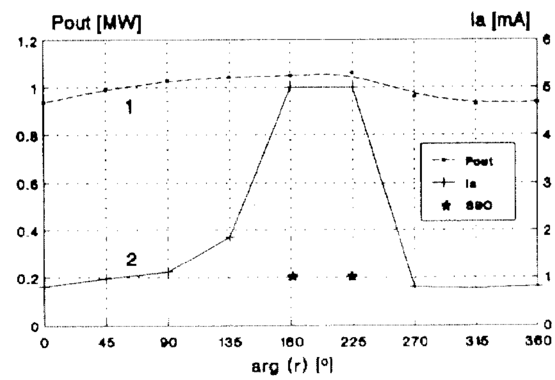

Fig. 1 Measured output power (1) and anode current (2) of YK 1303 with respect to reflection phase angle. The * indicates sideband oscillations.

with the change in output power depending of mismatch phase angle is given in Fig. 1. Interesting is the fact that sideband oscillations (SBO) starts when the klystron is undersaturated (e.g. Pin = 1 to 2 dB below saturation).

For a better understanding of these phenomena some simulations were made using the particle in cell program FCI [2,3]. In Fig. 2 one can see 4 pictures of the energy distribution of beam electrons in a klystron. Changing the load VSWR from 1.0 to 1.3 with the phase chosen to increase the loaded Q more and more electrons will be accelerated in opposite direction (indicated by energy values below 0) by high output gap voltage. Unfortunately this program is not designed to calculate the influence of backstreaming electrons to previous cavities. Therefore instabilities like self oscillations cannot be simulated. Fig. 3 shows the calculated influence of load mismatch (phase angel 0° and 180°) to efficiency and output gap voltage. The curve P_{back} gives the power of backstreaming electrons. The region where anode current spikes and sideband oscillations were observed is marked "unstable". For calculations of Fig. 3 a matched loaded Q of 41 was chosen to optimize the efficiency. By reducing this quantity the margin to the unstable region is increased - however, at the cost of efficiency. If a large range of load reflection conditions is desired it may therefore become neccessary to use this design approach giving up part of the efficiency which would be obtainable for matched operating conditions.

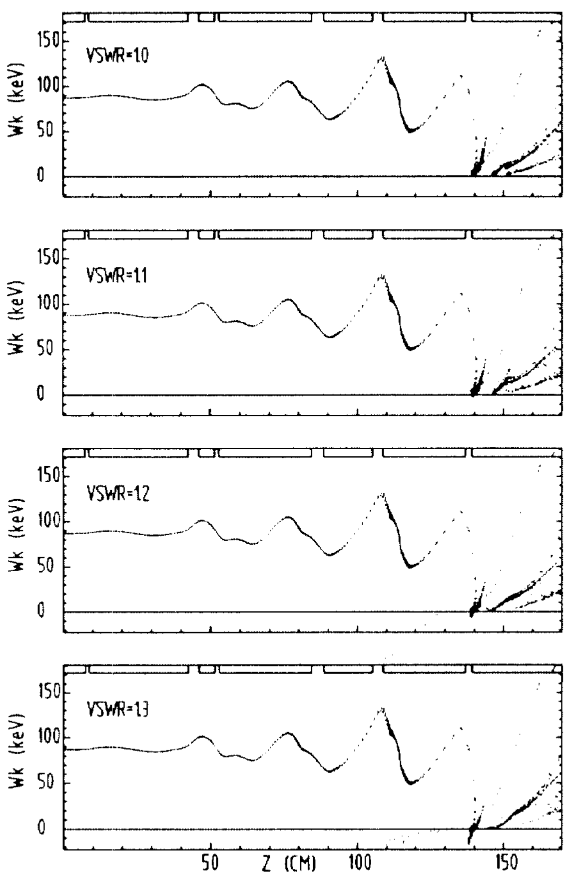

Fig. 2 Calculated particle energy distribution of YK1303 (Ub=90.3kV Ib=18.3A) under different load mismatch contitions.

In real klystrons another source for backstreaming particles are secondary and backscattered electrons from the collector region causing unstable operation even for smaller values of load reflections. Experiments on TV klystrons have shown a significant improvement of signal quality when depressing these electrons or preventing them from drifting back into RF section. One way is to coat the surface of collector region with carbon or TiN which have lower secondary emission coefficients than copper. The other way is to decrease the collector entrance diameter in order to reduce the number of backstreaming electrons.

The time dependant effect mentioned in charpter 1 can be explained by the following: During lifetime the cathode deposits Ba into the gun region and forms Ba layers also on the hot surface of Wehnelt zylinder. This hot layer emits electrons at the edge of the normal beam which are not properly focused and therefore either hits the anode directly or may be reflected by the high electric field in output gap due to their border position.

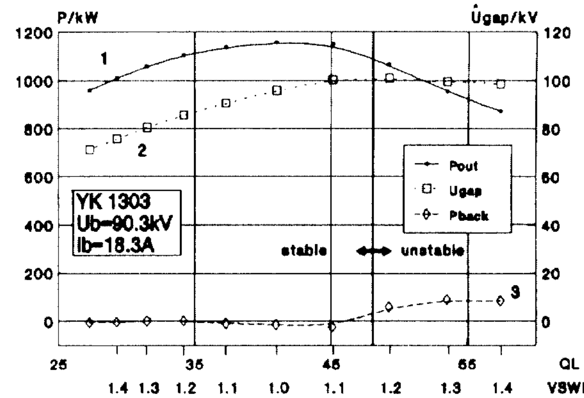

Fig. 3 Calculated output power (1), output gap voltage (2) and power of reflected electrons (3) with respect to mismatch VSWR.

3. RESULTS

One experiment we worked out on a YK1303 was to decrease the drift tube diameter at the transition gun - RF-section in order to hide the modulating anode ring from backstreaming electrons. At this point the beam diameter is small enough and is not effected by RF bunching. This modification led to a slight improvement in anode current but did not effect sideband oscillation. Another experiment

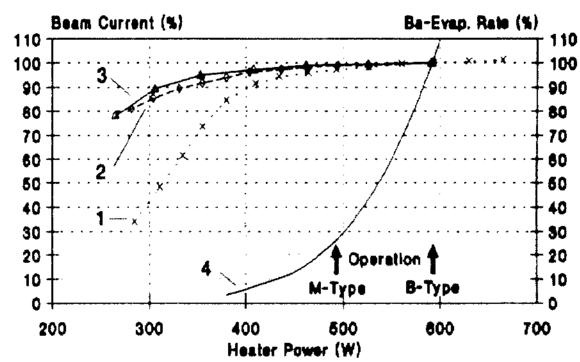

Fig. 4 Underheating plots for B-Type (1) and M-Type cathodes after 750h (2) and 5200h (3) and the Ba evaporation rate (4) normalized to B-Type operation point.

on two YK1303 was to additionally decrease collector entrance diameter in order to minimize the contribution of secondary and backscattered electrons. This diameter was chosen carefully by FCI-Simulation not to intercept the blown up beam. With this modification an otherwise unchanged klystron was significantly improved with respect to sideband oscillations and irregular anode current at larger values of load reflections.
In order to improve stability over lifetime we introduced a Os-Ru coated 'M'-cathode together with a special cathode pretreatement. Due to the lower work function of the Os-Ru cathode we could decrease the cathode temperature by 70 K without effecting emission and therefore reduced Ba deposition dramatically (see fig. 4).

4. REFERENCES

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