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DESIGN IMPROVEMENTS IN HIGH POWER KLYSTRONS FOR ACCELERATOR APPLICATIONS

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ABSTRACT Due to high energy costs the first design goal for power klystrons working at power levels of 1 MW was an ultimate efficiency exceeding 65 %.
During years of experience with these tubes it turned out however that the operational stability of these tubes in application became of equal importance. A program has been started to improve the operational stability of the tubes for CERN, DESY and KEK applications. The paper describes measures and progress in this field.

Introduction of an electron gun with improved thermal structure

During the development of power klystrons with power levels above 1 MW the behaviour of the anode current appeared to be of major importance.
Fig. 1 shows the dependence of anode current with increased heater power at a previous gun design of a YK 1301 for DESY. A high level of thermal emission from the Wehnelt electrode at increased heater power levels resulted in an anode current which sometimes exceeded the capability of the equipment. The operating point was a compromise between this limit and a sufficient space charge operation of the cathode. An improved design with refined cooling of the electrodes is now incorporated in all Philips tubes and results in an

uncritical behaviour (tube 3 and 4).

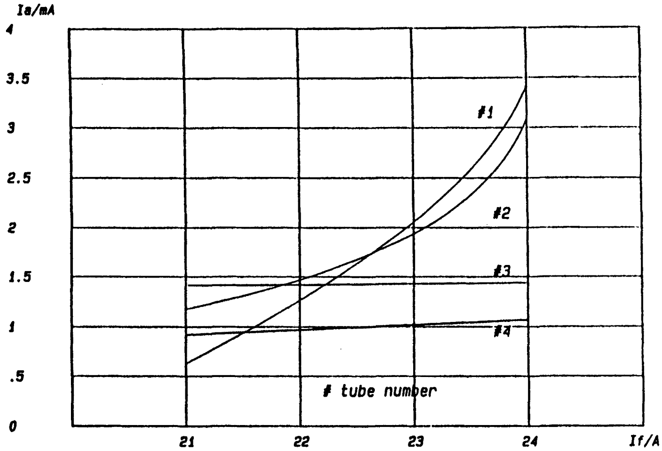

Fig.1: Thermal anode current

Fig. 2 shows a lifetime effect at a gun design for a previous KEK-tube YK 1302 due to deposition of Barium on the Wehnelt electrode which resulted in an increased anode current after some 1000 operating hours. Sometimes the emission of electrons by the anode caused even a negative level of anode current which entailed problems in the anode power supply. The improved design gets rid of these deficiencies as well (tubes 4, 5 and 6).

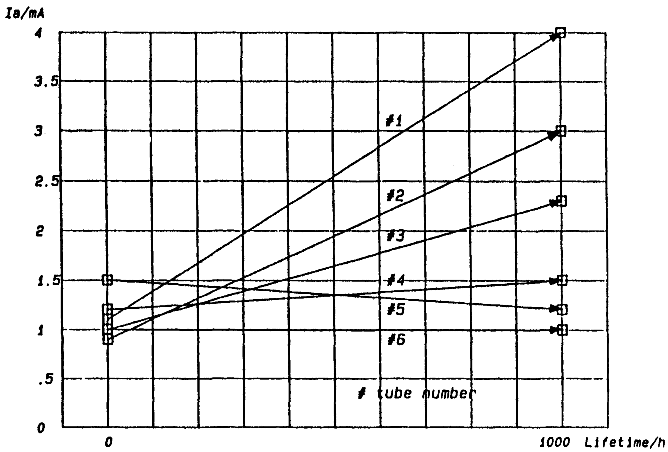

Fig.2: Anode current over lifetime

BEAM CONTROL

Application requests often for stand-by operation the control of beam current and power output completely by means of the anode voltage keeping full beam voltage applied. Problems arose with old electron gun designs at low beam current levels. Unbalanced space charge forces caused the beam to defocus resulting in strongly increasing power dissipation in the body sections. Fig. 3 shows power dissipation in the body sections exceeding 3 kW at beam currents below 4 Amps at the old design B.

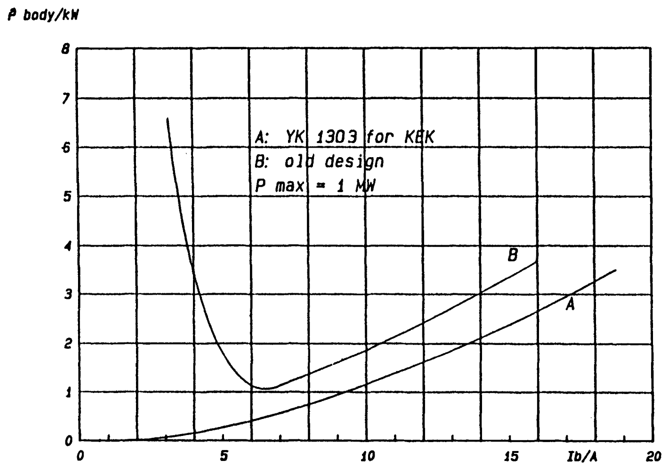

Fig.3: Body power dissipation

Improvements have been made in beam optics to get rid of these deficiencies at low current levels. Fig. 3, curve A shows the optimized design incorporated into the KEK-tubes YK 1303. The beam can be cut off completely. In addition, an improvement in power dissipation level by about 1 kW at the normal high current operating point can be perceived. Care has to be taken in low current operation concerning the local power dissipation in the collector. Due to the decreasing perveance the beam remains confined in the collector region resulting in a hot spot at the collector end.

SPURIOUS SIGNALS

Inherent to the design of high efficiency klystrons working at MW power levels is the susceptibility to generate spurious sideband signals. These signals appear at designs of different manufacturers and applications, Frischholz [1].
The sideband signals depend strongly on operation parameters like beam voltage and current, beam focusing, Rf-drive level and Rf-load conditions. They appear typically at Rf drive levels of 1-3 dB below saturation of the tube and above saturation. These sideband signals are accompanied by an increased level of anode current.

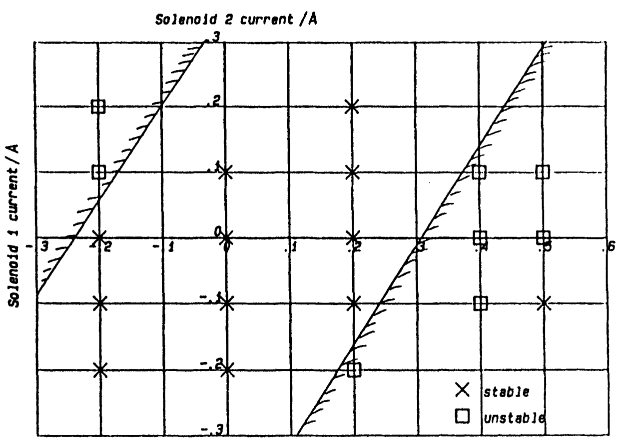

Fig.4: Stable operating region of YK 1303

Fig. 4 shows a field of solenoid 1 and 2 values where the tube is free of sideband signals. It recently has been observed that this stable operating region changes with lifetime of the tube.

With increasing lifetime these areas free of unwanted sideband signals narrow, an effect which limits the degrees of freedom for optimising other parameters eg. collector beam distribution.

The bandwidth of the output cavity effects the tendency for instable operation of the tube as well. Normally the bandwidth of the output circuit is optimized with respect to efficiency (optimum gap impedance). On the other hand it has been observed that increased bandwidth (reduced efficiency) also reduces the tendency for instabilities. So the chosen bandwidth is a compromise.

The frequency characteristic (amplitude and phase) of the load influences the tendency for sideband signals. A broad-band well matched load increases the stability. Also at the frequencies of the observed sideband signals the load should be matched.

It has been observed that the frequencies of the sideband signals are related to the frequencies of the high Q buncher cavities. The signals appear at distinct frequencies beside the main operating frequency. They are effected directly by tuning of the buncher cavities.

From these observations and other experiences it can be concluded that the following mechanisms may be involved in the generation of unwanted sideband signals:

1. Multipactoring in buncher cavities
2. Feedback mechanisms by backstreaming electrons as a result of high efficiency operation. Possible sources are the output gap or the collector

Experiments have shown that the anode is not actively involved in generation of the signals.

Based on the analysis of the observations an improvement program has been started.
First positive results have been achieved at a YK1350 design by optimisation of the output coupling of the tube and measures in the cavities.
Similar and further measures are on their way now for the KEK tubes YK1303.

1. H. Frischholz, 1989 Particle Accelerator Conference, Chicago