# CERN – European Organization for Nuclear Research
**European Laboratory for Particle Physics**

**CTF3 Note 030 (Min.)**
**PS/PO/Note 2001-048 (Tech.)**
**(Broadband Klystron)**

# NOTES OF A VISIT TO TMD TECHNOLOGIES LTD. ON 2ND AUGUST 2001

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Geneva, Switzerland
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# Notes of a visit to TMD Technologies Ltd on 2nd August 2001

**CERN people present:-** Peter Pearce, Gerard McMonagle, Ivo Lobmaier

**TMD people present:-** Howard Smith, Graham Phillips, George Wakeman,
Roger Gates, Guy Howard

The objectives for this visit to the TMD plant at Hayes, Middlesex, UK were discuss the technical design proposal EVT 2459, received in April 2001, and review the various options for the manufacture of a low-power, broadband klystron operating at a frequency of 1.5 GHz. In addition, we needed to discuss details for the supply of CERN test modulator equipment to allow TMD to be able to fully test this klystron once manufactured. Linked with both of these subjects was the discussion of total manufacturing costs to CERN for this special, one-off (an option for a second is included) klystron to be used in the CTF3 test facility. For this reason, Ivo Lobmaier from the SPL division was present.

The meeting agenda was agreed as:

1. TMD company presentation
2. Technical discussion of the design report and manufacturing options
3. Cost drivers and reducers, and time scales
4. Test modulator and other test components needed
5. Other components for the total system

The TMD presentation gave Gerard McMonagle and Ivo Lobmaier a fuller picture of the company. These two persons were not able to be present at the TMD-CERN meeting in June of this year.

**The technical discussion**

Aspects of the design report led into detailing the different manufacturing options required by CERN for this klystron.

a) The klystron gun is to be a Pierce type gun and the option for having a control grid has been dropped. This should make the overall gun design easier and most likely improve reliability and there is no problem from TMDs point of view. The cathode lifetime given for this klystron is 50,000 hours. However, many other things can shorten this figure to a more practical 25,000 hours of useful klystron operation.

b) Output method to extract RF power from the klystron. CERN has asked that the output cavity be designed such that a half-height waveguide coming from it will taper up to a full standard WR650 waveguide window size. The original klystron used to derive this broadband klystron design (PT6006) had a coaxial output which then connected to a coaxial-to-waveguide conversion piece after the coaxial klystron window. This change is not a problem for the design of this klystron.

c) A RF window for 1.3 GHz design exists and will have to be recalculated for the new frequency (1.5 GHz) and 10% broadband response requirements.

d) The overall mechanical design for the klystron forms part of the total design for manufacture. The dimensions at the gun end and any peculiarities here are particularly important to CERN since we propose to modify an existing S-band klystron tank for this task. The modified tank will be required for testing the klystron at the TMD plant.

e) The focal coil design for the PT6006 is a high-voltage, low-current device and was proposed by TMD for the broadband klystron. CERN has a preference to use low-voltage, high-current coils in order to standardize on the type of focal power units already in operation with the other klystron-modulators. The low-voltage coil preference will be included by TMD in the manufacturing design.

f) Klystron gain. The klystron design proposed has eight cavities that will provide an overall gain within the bandwidth of about 40 dB. This means that a solid-state driver with a minimum output power of 50 Watts (100 W practical) would be able to saturate the 0.5 MW, peak output power klystron.

g) The phase pushing figure calculated by CERN and TMD was agreed upon as 0.0191 degrees per volt, and when looked at with the probable voltage slope of 0.1% on the pulse voltage flat top would mean a total phase change of 1.3 degrees over the full pulse width.

h) The broadband characteristics are given as 150 MHz minimum as asked for. The overall predicted characteristics for the klystron are shown in the accompanying table.

**Cost drivers**

TMD have verbally indicated that this klystron will cost around 1.5 MCHF. This figure is 50% above the ~1 MCHF estimated previously at CERN. TMD say that although the design started with the existing PT6006, the actual design effort required to create the klystron to our specification is more costly. This does not just mean a frequency change and an increase in bandwidth, but also increasing the peak power by a factor five. A beam stick hot model will have to be made to prove the design before a production tube can be manufactured. This beam stick will be CERN property afterwards and could be used as a diode load. Also, more parts than required for a single tube will have to be manufactured in case of a problem during this and the testing phase. A complete new set of manufacturing drawings will also be required for this klystron. The cost of testing also has an effect on the overall price. Taking all of these factors into account and the prevailing manufacturing risk for any new tube type TMD believe the cost (a formal offer has yet to be sent) is justified. The time scales indicated are for CERN to have a broadband klystron from the end of March 2003 earliest. A second klystron may be purchased later.

**Test modulator**

The provision of a test modulator that will power the broadband klystron is necessary since TMD do not have an appropriate test system in their plant. A compact solid-state modulator is actually being developed in CERN for this application. It is proposed that CERN loans this modulator, free of charge, with its high-voltage charging unit and a klystron tank to TMD so that the latter can test the finished klystron to specification. Originally TMD asked also for a L-band load, but on reflection they find that two such loads exist in their factory. Additionally, CERN will have to supply a broadband solid-state driver amplifier, or buy one from TMD for them to use for our tests.

The CERN test modulator, when completed and tested with a dummy load can be sent to the TMD plant for a specific period. CERN will have to set up the test modulator at the TMD plant and operate it into a diode or dummy resistive load to show that its characteristics match those required for the klystron test. The modulator high-voltage installation and set-up periods would then be followed by the RF testing period. This would be under the responsibility of TMD.
The participation of a CERN person would probably be needed for each of these three periods for one week at a time.

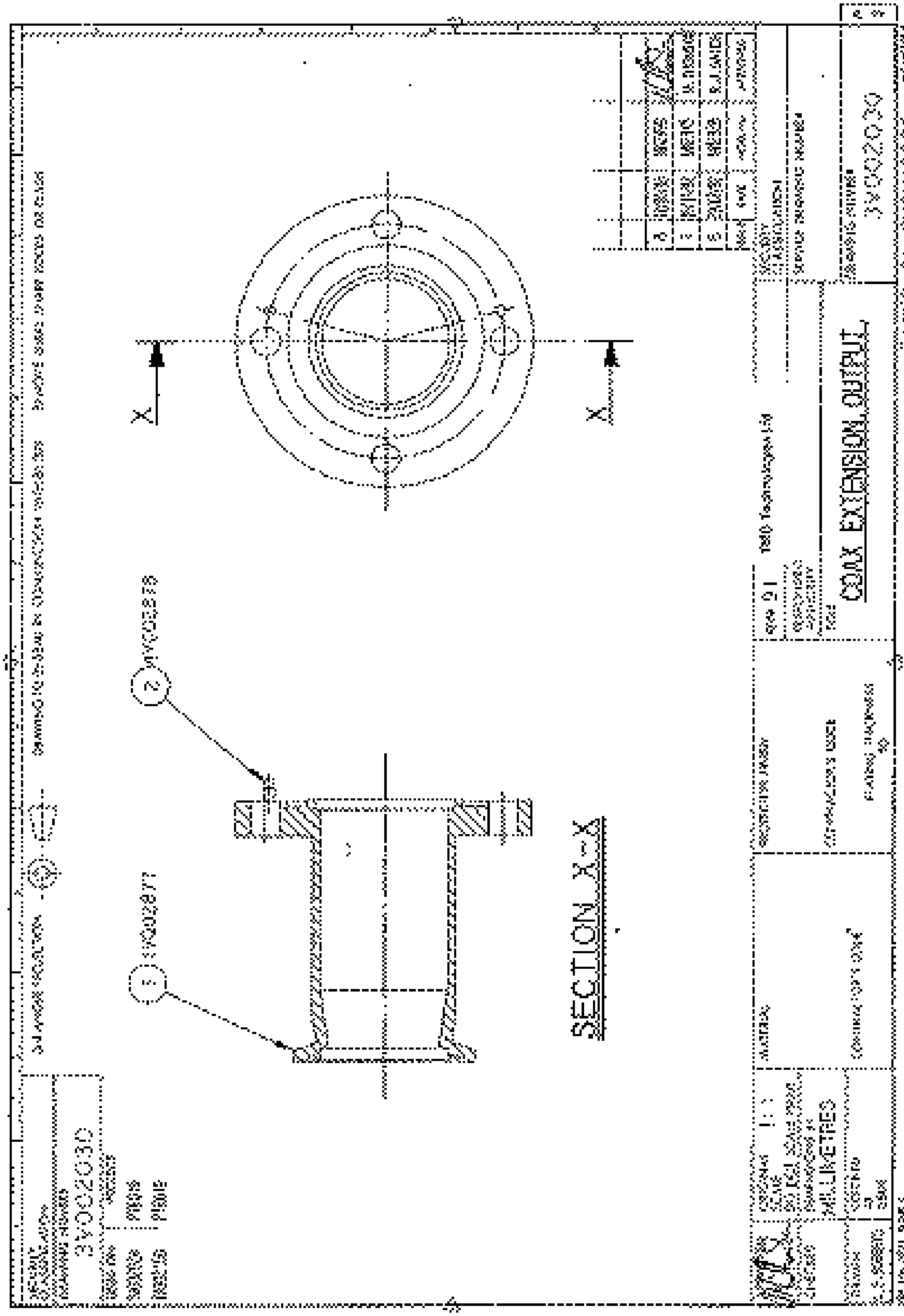
**Fault detection**

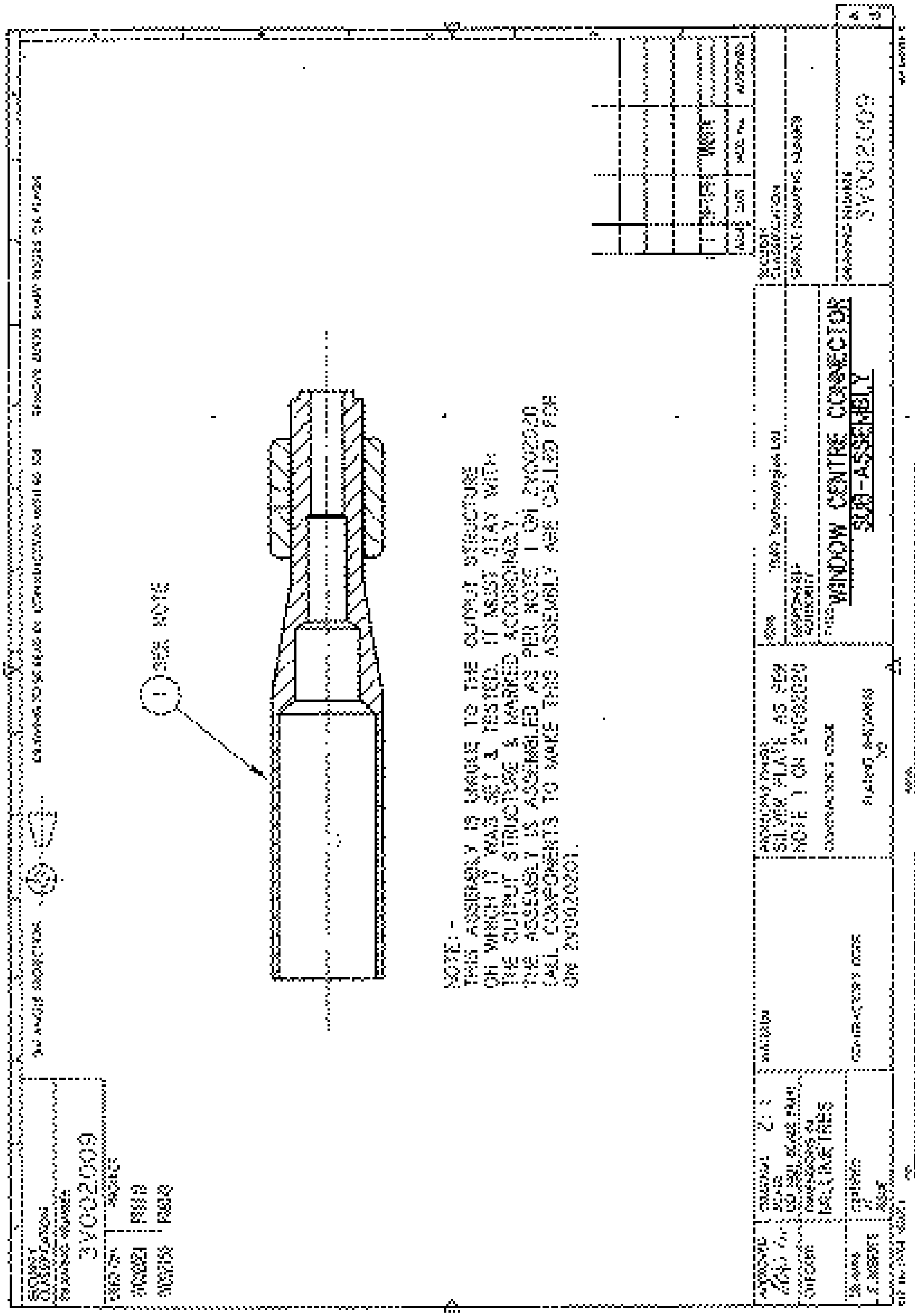
For detecting current arcs in the klystron gun region during testing and when in operation, TMD prefer CERN to use the detection of the ion pump current rise (since it is more direct and will be faster. This is not a problem as this is already interlocked in the existing CERN modulators.

**Other RF components needed for the complete system**

TMD manufacture solid-state driver amplifiers but also can indicate to CERN other manufacturers of similar devices that would be suitable. They are linked into a grouping of RF component manufacturers that include mostly French companies from the Brive area of France. ATMH is a company well known to CERN for its expertise in special waveguide manufacture, as well as Prana, a company making solid-state amplifiers. According to TMD the link with this group is operational but weak, and we can address offers directly to TMD as well as to other members in the group. These could be amplifiers or waveguide components such as couplers, windows, loads, phase shifters, power splitters or attenuators.

The special requirement for introducing the RF power into the SHB cavities (three of them) can be made with an adaptation of the existing TMD transition piece going from coaxial to waveguide. This works in both directions. The metal coaxial connection is about 1.5 inch diameter and has been used for >100 kW pulses. It can be designed to negotiate corners to avoid the beam focusing coils and will access spaces of less than 10cm diameter. The drawings for the existing piece are attached.


SECTION X-X
COAX EXTENSION OUTPUT
3V002030
MILLIMETRES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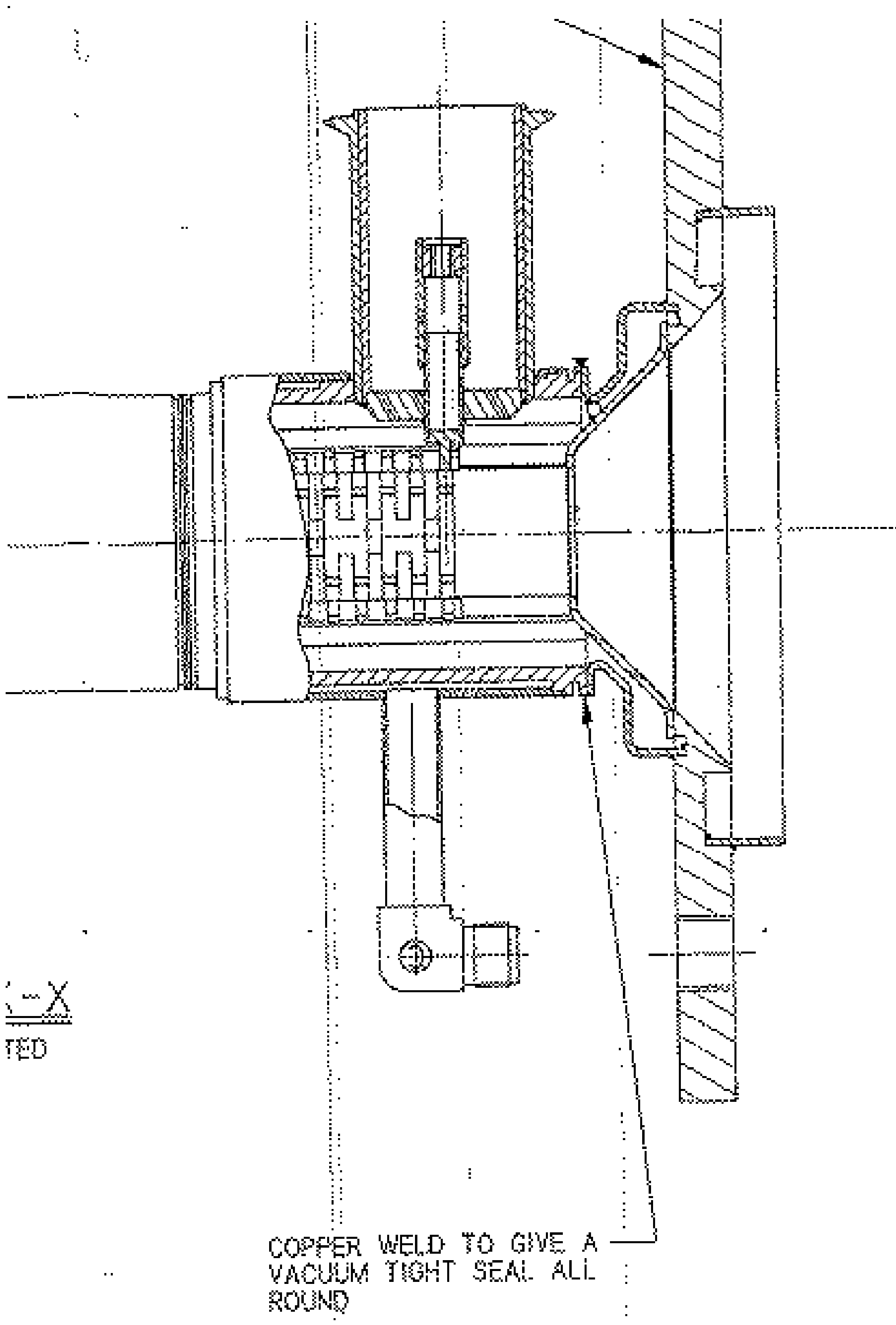
1 SEE NOTE
NOTE: -
THIS ASSEMBLY IS UNIQUE TO THE OUTPUT STRUCTURE
ON WHICH IT WAS SET & TESTED. IT MUST STAY WITH
THE OUTPUT STRUCTURE & MARKED ACCORDINGLY.
THE ASSEMBLY IS ASSEMBLED AS PER NOTE 1 ON 2Y002020
CALL COMPONENTS TO MAKE THIS ASSEMBLY ARE CALLED FOR
ON 2Y0020201.
SILVER PLATE AS PER
NOTE 1 ON 2Y002020
MILLIMETRES
WINDOW CENTRE CONNECTOR
SUB-ASSEMBLY
3Y002009



COPPER WELD TO GIVE A VACUUM TIGHT SEAL ALL ROUND

## 3. PREDICTED CHARACTERISTICS OF KLYSTRON

The predicted performance of the proposed klystron has been considered under three headings:-

i) The specified CERN requirement.

ii) The designed performance.

iii) The expected limits of performance.

| PARAMETER | CERN Requirement | Design Performance | Performance Limits |
|---|---|---|---|
| **PERFORMANCE** | | | |
| Peak output Power | >= 500 kW | 757 kW | 1000 kW |
| Centre Frequency | 1500 MHz | 1500 MHz | N/A |
| Bandwidth | >150 MHz | >150 MHz | >150 MHz |
| Duty Cycle | 0.002% | 0.002 % | 1.0% |
| Pulse Width | 2.0 E-6 | 2.0 E-6 | 100 E-6 |
| Efficiency | >20% | 25% | 29% |
| Gain | >30 dB | 40 dB | 40 dB |
| Bandpass Flatness | N/A | < 1.0 dB | < 3.0 dB |
| Phase Pushing | N/A | | |
| | | | |
| **OPERATING PARAMETERS** | | | |
| EHT Voltage | N/A | 69 kV | 85 kV |
| Peak Beam Current | N/A | 36.6 A | 45 A |
| Magnetic Focusing Field | N/A | 0.07 T | N/A |
| Heater Voltage | N/A | 13.0 V | 15 V |
| Heater Current | N/A | 15.0 A | 18 A |
| Solenoid Voltage | N/A | 100 V | N/A |
| Solenoid Current | N/A | 18 A | N/A |
| | | | |
| **PHYSICAL PARAMETERS** | | | |
| Length | N/A | 1490 mm | N/A |
| Weight - Tube | N/A | 80 kg | N/A |
| Weight - Solenoid | N/A | 287 kg | N/A |