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USER OPERATION AND MAINTENANCE MANUAL

W-band Interferometer
Part No. RMM-10/94/200/10

1st Edition
June 2008

Table of Contents.

1. INTRODUCTION.

This instruction manual contains information on installation and operation of the W-band Interferometer.

1.1 General Description.

W-band interferometer is intended for measuring the line-averaged density of plasma along the path through which the mm-wave beam is passed, through phase shifts in the propagated beam.

Base principle of operation is an effect of change of phase speed of electromagnetic waves of a millimeter range in plasma depending on density.

2. SPECIFICATIONS.

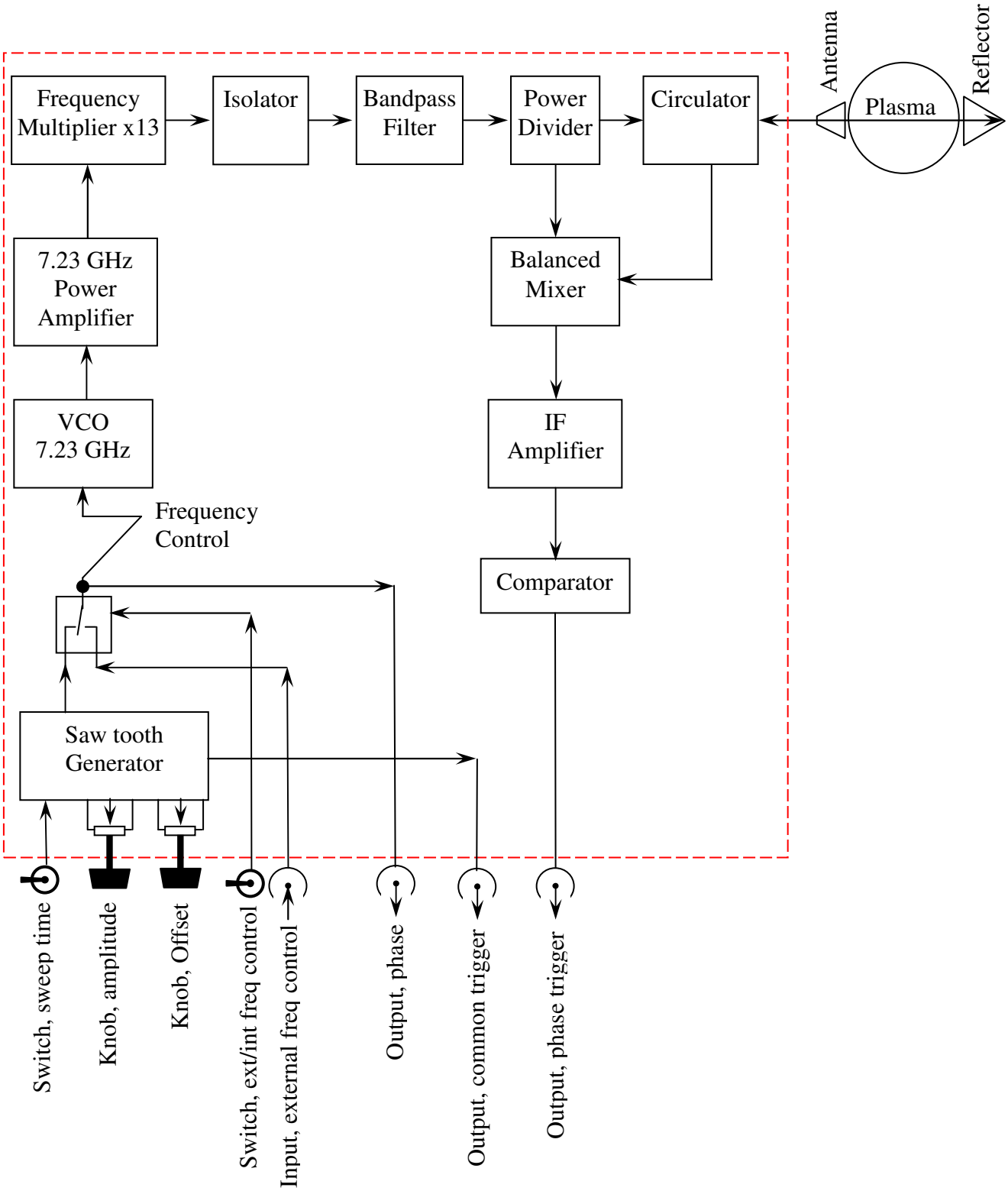
2.1 Electrical Specifications.

1. Center Frequency	94 GHz
2. Frequency Stability	5*10-6 1/°C
3. Sweep range	500 MHz;
4. Minimal Sweeping Time	10 uSec (external control)
5. Linearity	0,7% (max)
6. Tuning sensitivity	>50 MHz/V
7. Output RF Power	+10 dBm (min)
8. Reverse Isolation	17 dB (min)
9. IF Frequency	4 kHz to 4 MHz
10. RF to IF Gain	32 dB (typ)
11. Waveguide	WR-10
12. Flange	UG-387/U-M
13. Antenna gain	30 dB
14. AC Power	220 VAC
15. Operating temperature range:	+10°C…+ 50°C;

2.2 Mechanical Specifications.

1. Size	470x120x250 mm;
2. Weight	8 kg.

2.3 Block-diagram of the interferometer.



Picture No1. Block-Diagram of the interferometer.

2. 4 Principle of operation.

The interferometer is built at Wharton scheme of interferometer with sweeping frequency. Transmitter and receiver are integrated into one case and connected via circulator, such way transmitted and received signals go thought one waveguide channel, see block-diagram of the system.

Two signals come to the balance mixer:

- reference signal via power divider
- signal passes thought the plasma

These signals can be expressed as:

$E_r = E_r \cdot \cos(\omega t + \alpha)$ - ref path;

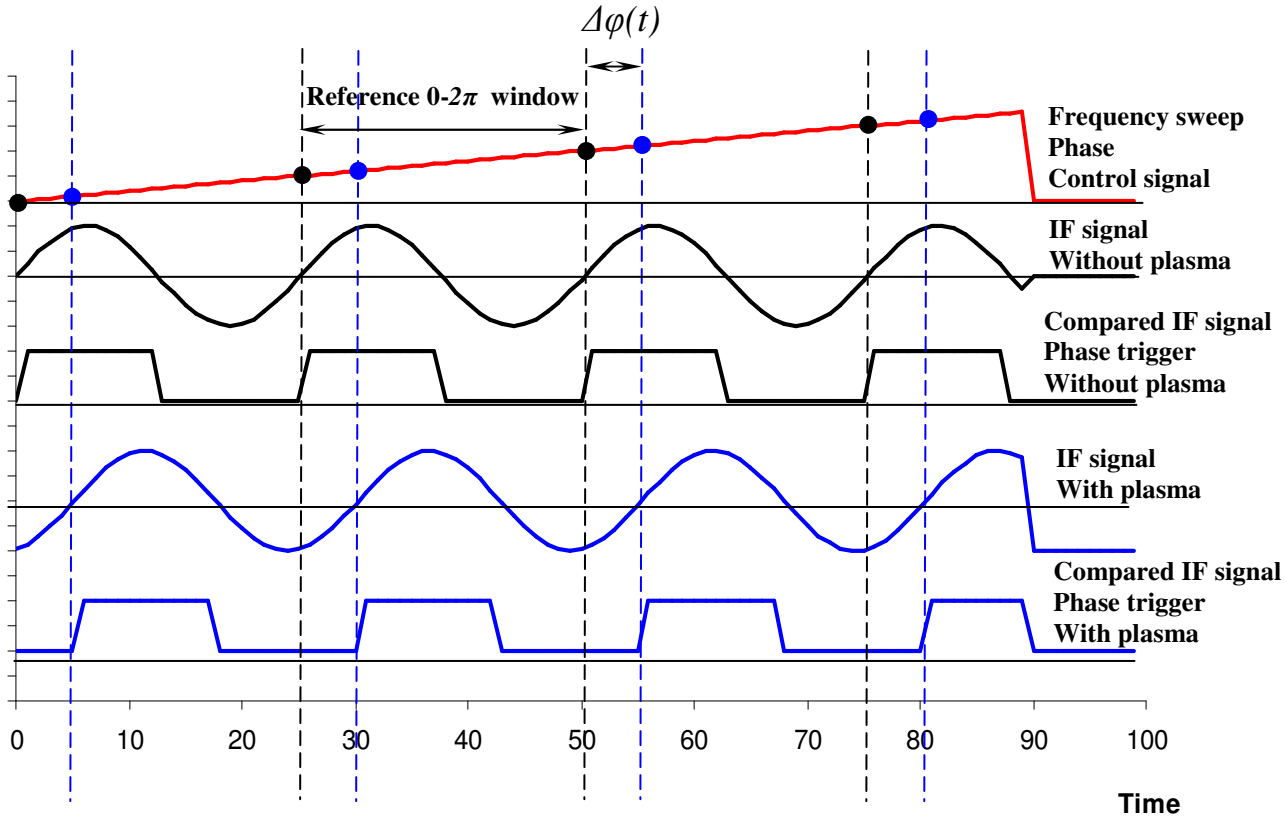
$E_p = E_p \cdot \cos(\omega t + k(\omega))$ - plasma path;

The result of mixing is time -varying IF output signal:

$$i_s = E_p E_r \cos(2\pi t \frac{d\nu}{dt} \Delta t - \Delta\varphi(t)); \text{ where,}$$

$\frac{d\nu}{dt}\Delta t$ - changing phase, determined with long of optic way and width of frequency sweep

$\Delta\varphi(t)$- phase different between two signals, determined with plasma density. In absence of plasma, $\Delta\varphi(t)=0$. See picture No2.



Picture No2. Time diagram of signals in interferometer.

Plasma occurrence will provide $\Delta\varphi(t) \neq 0$, such way to shift IF signal from the initial phase reference points ($\Delta\varphi(t)=0$). See Picture No2.

Based on plasma physics theory, phase shift can be expressed as:

$$N_{2\pi} = \frac{1.345 \cdot 10^{-16}}{\nu} < n_e > L,$$

where

$N_{2\pi}$ - $\Delta\varphi/2\pi$, $\Delta\varphi$ in radians;

n_e - density of plasma, in m-3;

L - length of optic way in plasma, in m;

ν - Transmitted frequency, in GHz.

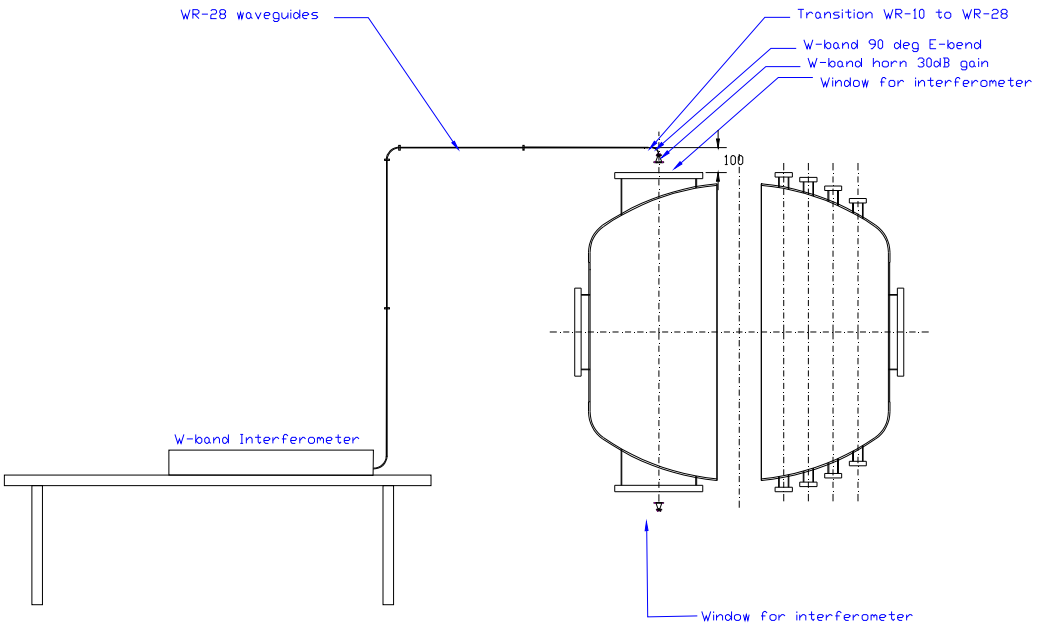
After transformation of this formula and remember, that our signal passes through the plasma twice, we have the following:

$$n_e = \frac{2.366 \cdot 10^{15} \cdot \Delta\varphi \cdot \nu}{L}, \text{ m-3}$$

3. Installation and Functional Tests.

3. 1. Assembly procedure.

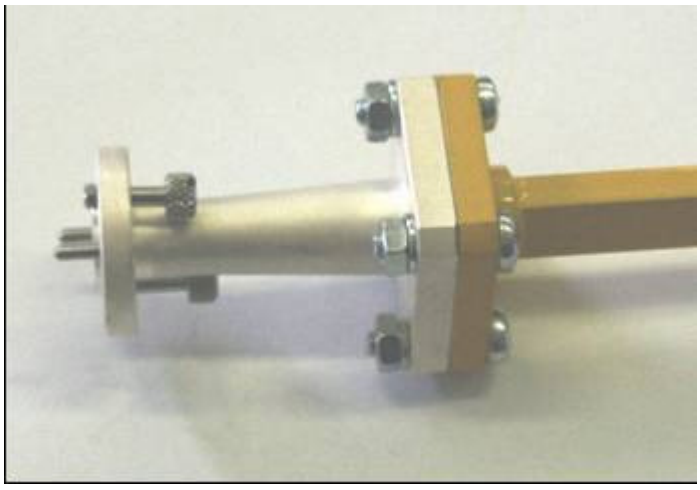
The interferometer can be installed directly near windows of TAKAMAK or removed from it by extension WR-28 waveguides, as it presented on picture below.



Picture No3. Example of setup of interferometer.

Waveguide's set of the interferometer consists of the following components:

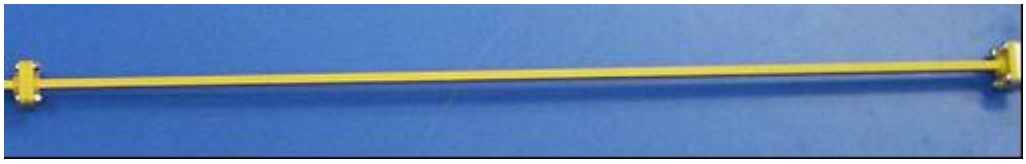
- Waveguide transition WR-10/ UG-387/U-M to WR-28 / UG-599



- 30 dB Horn len's antenna WR-10/ UG-387/U-M

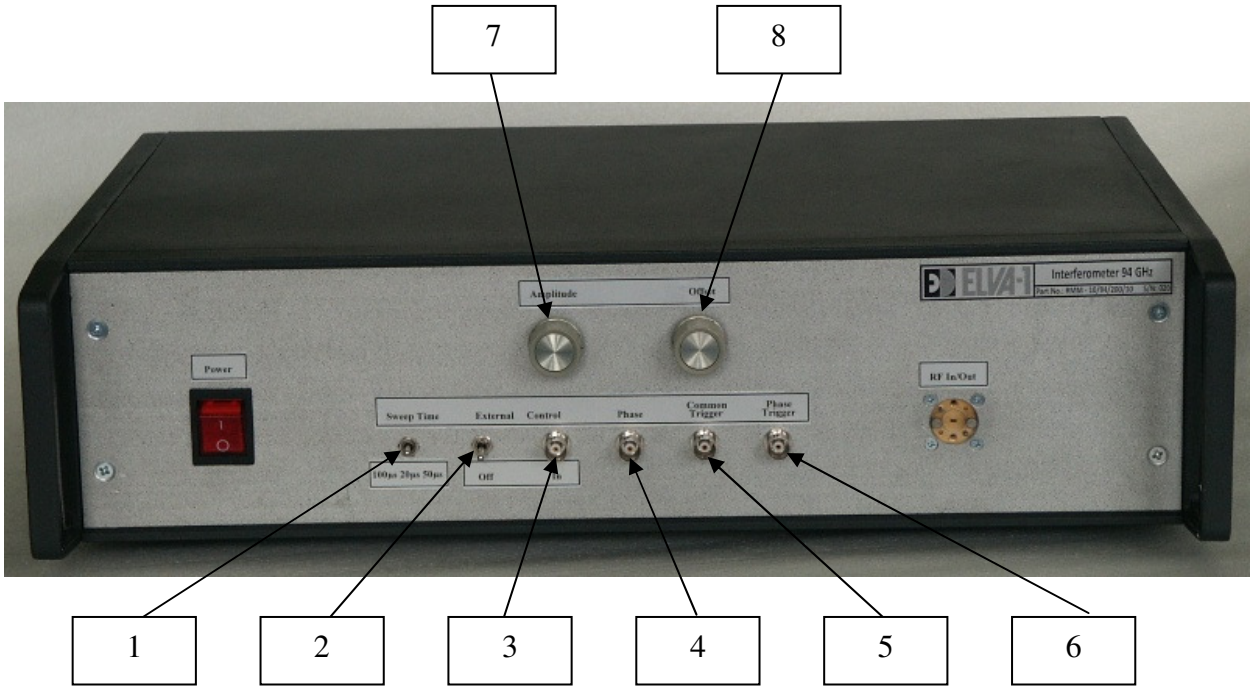
- Waveguide bend WR-28/ UG-599

- Extension WR-28 waveguides, length 50-70 cm



The user can assemble waveguides in any order according to presented situation.

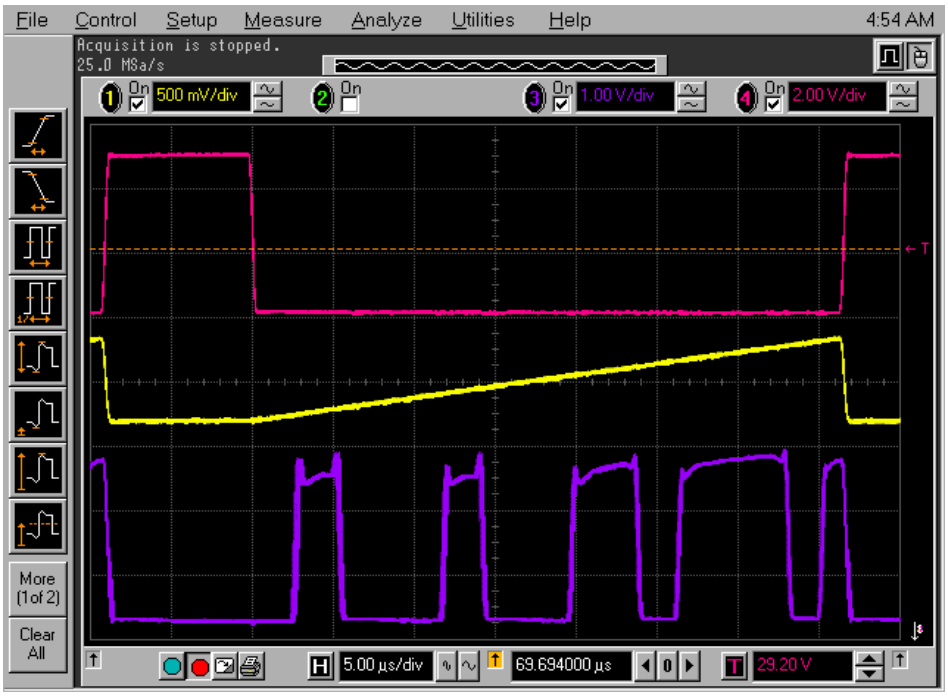
After setting waveguides the following connection according block-diagram of the interferometer should be done:



Picture No4. Front panel of interferometer.

1. Sweep time, switch, set sweep time 20, 50 and 100 μs;
2. Control output frequency, switch, set external or internal mode operation;
3. Input for external frequency control voltage, +7 - +11 V (BNC);
4. Output of phase level, sow tooth signal, -5 …+5V, should be connected to data acquisition system;
5. Output of Common trigger, TTL, should be connected to data acquisition system;
6. Output of phase trigger, TTL, should be connected to data acquisition system;
7. Knob Amplitude, set width of frequency sweep;
8. Knob offset, set central frequency for sweep.

After assembling procedure, set frequency control mode and select sweep time by switch No1 (internal frequency control mode). Switch the device ON and controlling output signals to get 3-8 pulses on phase trigger output. Correct signals are presented on Picture No5



Picture No5. Real Time diagram of signals from interferometer.

To achieve correct signals knobs Amplitude and Offset should be used.

- Knob Amplitude controls quantity of phase trigger pulses during one sweep
- Knob Offset optimizes stability of amplitude of phase trigger pulses.

4. Supplement No1. Table output frequency and power vs. control voltage

Ucontrol, V	fout, GHz	Pout, mW
8.75	93.6	10.0
8.90	93.7	10.3
9.04	93.8	10.8
9.18	93.9	11.7
9.32	94.0	12.1
9.46	94.1	12.0
9.60	94.2	11.4
9.74	94.3	10.7
9.88	94.4	10.6
10.02	94.5	11.1
10.16	94.6	11.3
10.30	94.7	10.8
10.44	94.8	10.5
10.57	94.9	10.0
10.71	95.0	9.5