Broadband Microwave Emission Spectrum Associated With Kinetic Instabilities in ECR Plasmas

Ivan Izotov, Taneli Kalvas, Hannu Koivisto, Jani Komppula, Risto Kronholm, Janne Laulainen, Dmitry Mansfeld, Vadim Skalyga, Olli Tarvainen

JYVÄSKYLÄN YLIOPISTO
UNIVERSITY OF JYVÄSKYLÄ

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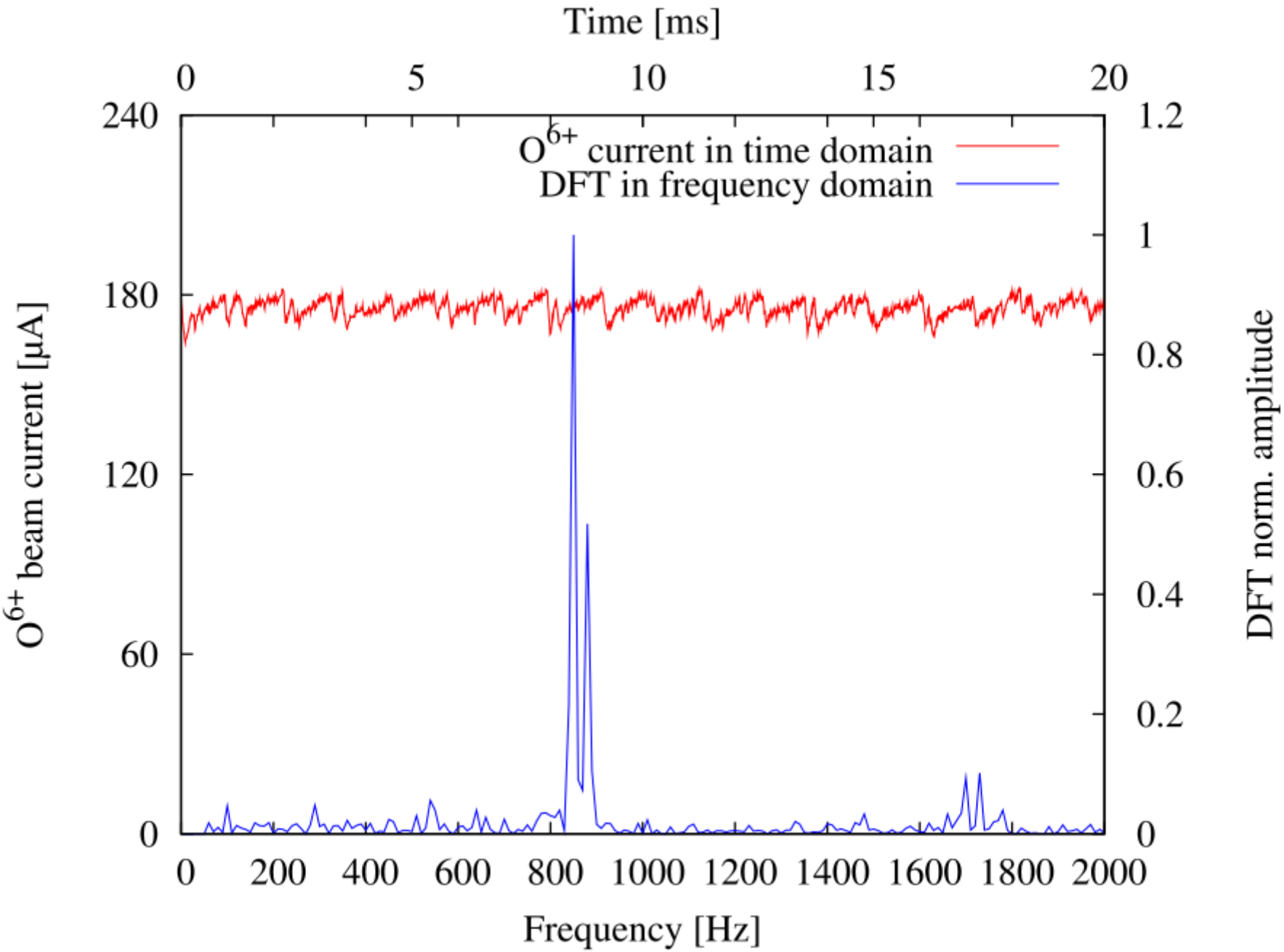
Outline

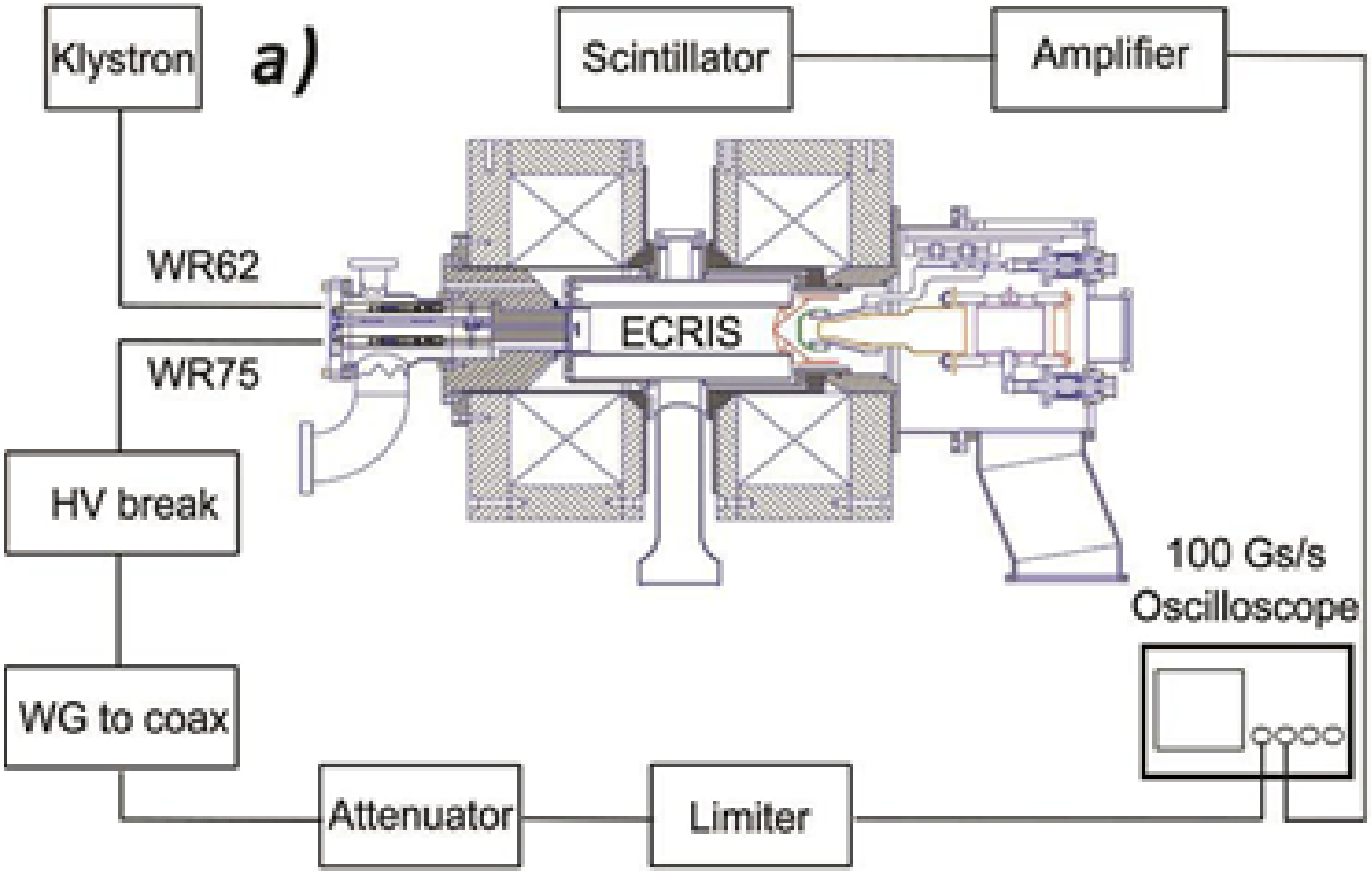
- Reminder: previous works on cyclotron instabilities and its affect on beam currents etc.
- Improved setup for wider frequency band and double-frequency heating simultaneously with microwave measurements
- Examples of wide band emission in case of different heating frequencies
- Quasi-linear “CW” emission: theory and the first experimental observation
- Open-space electromagnetic emission
- Conclusion

Beam current oscillations

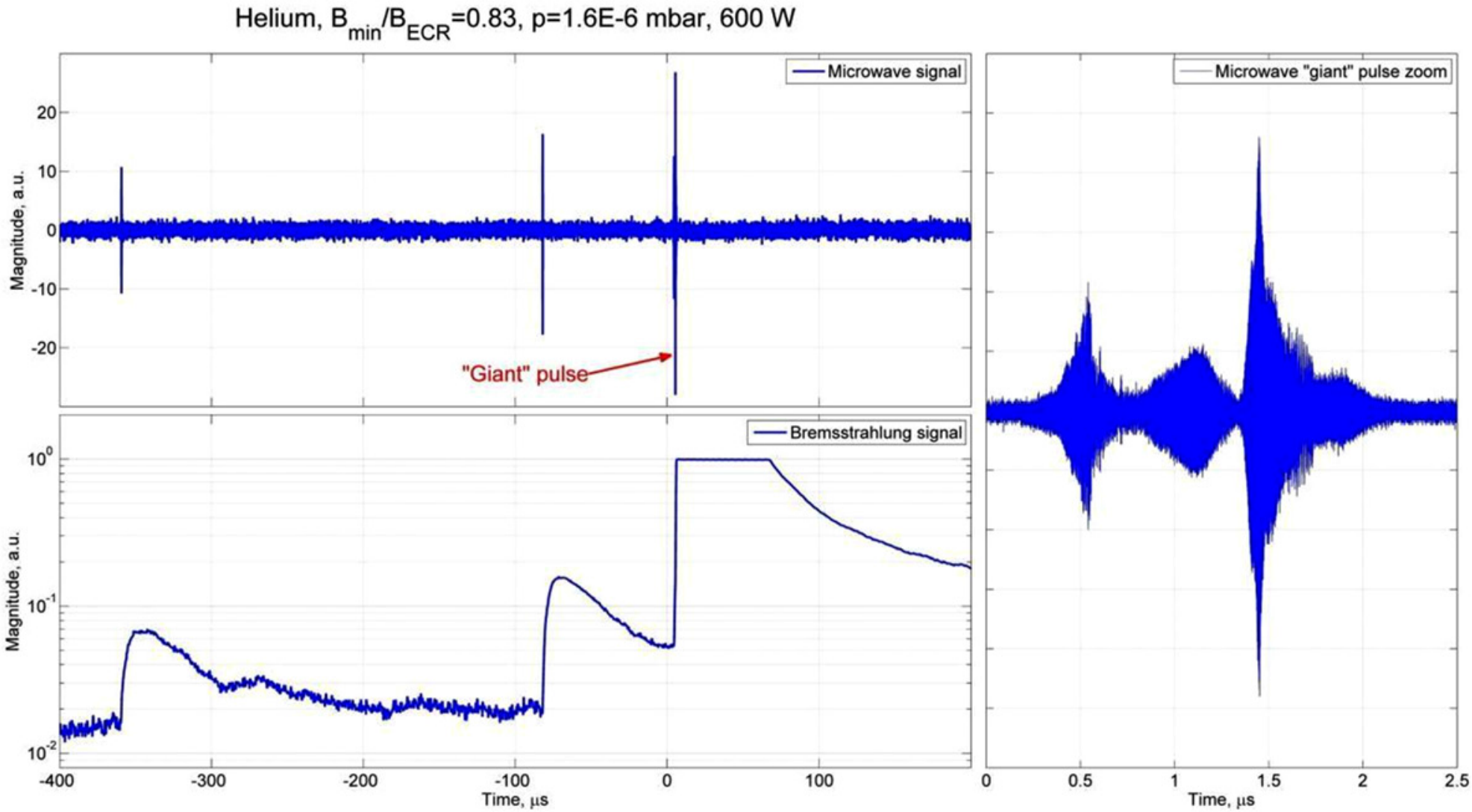


Tarvainen et all, Review of Scientific Instruments 86, 023301 (2015); doi: 10.1063/1.4906804

Previous scheme



Izotov et all, Plasma Sources Sci. Technol. 24 (2015) 045017 (9pp) doi:10.1088/0963-0252/24/4/045017



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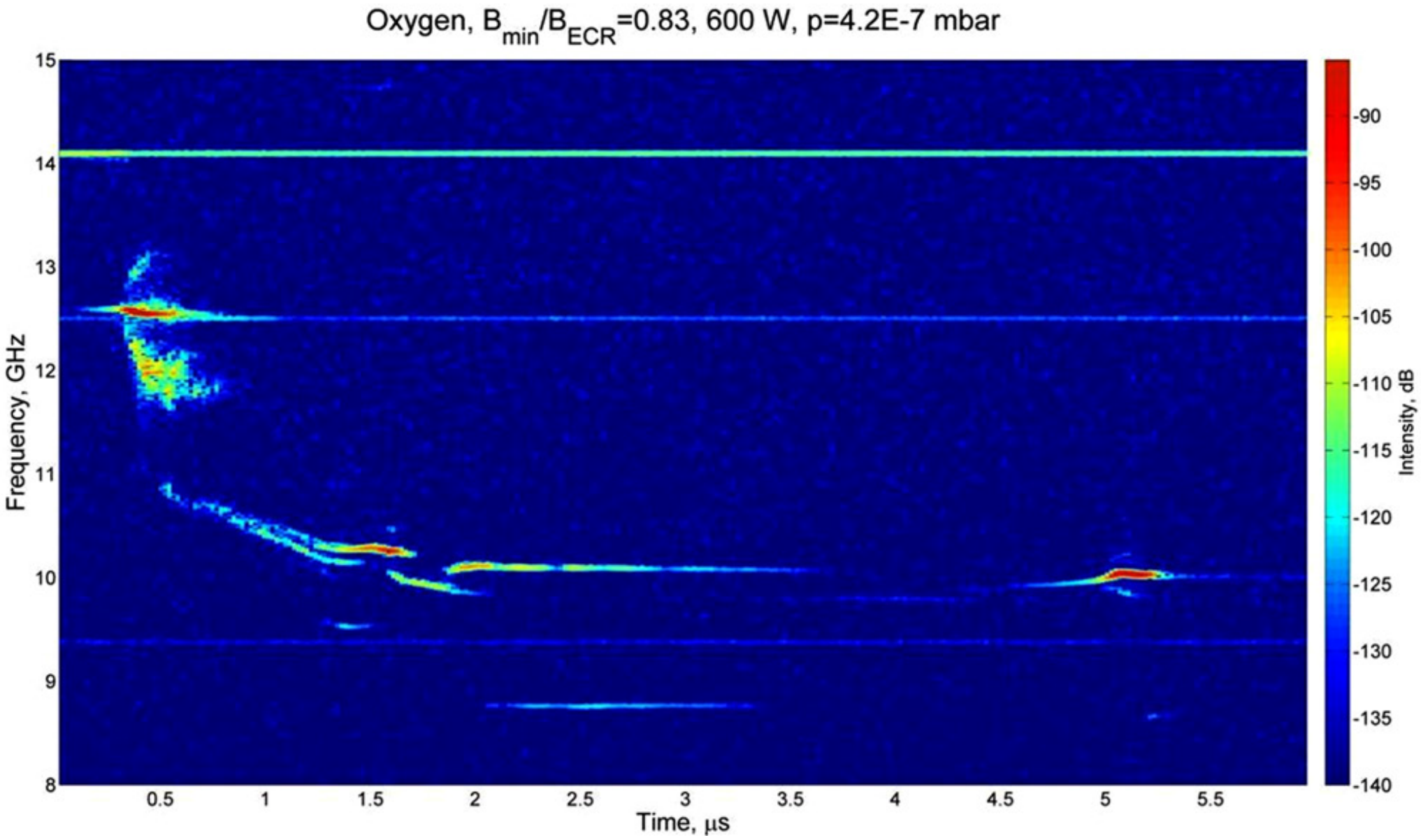
1. Introduction



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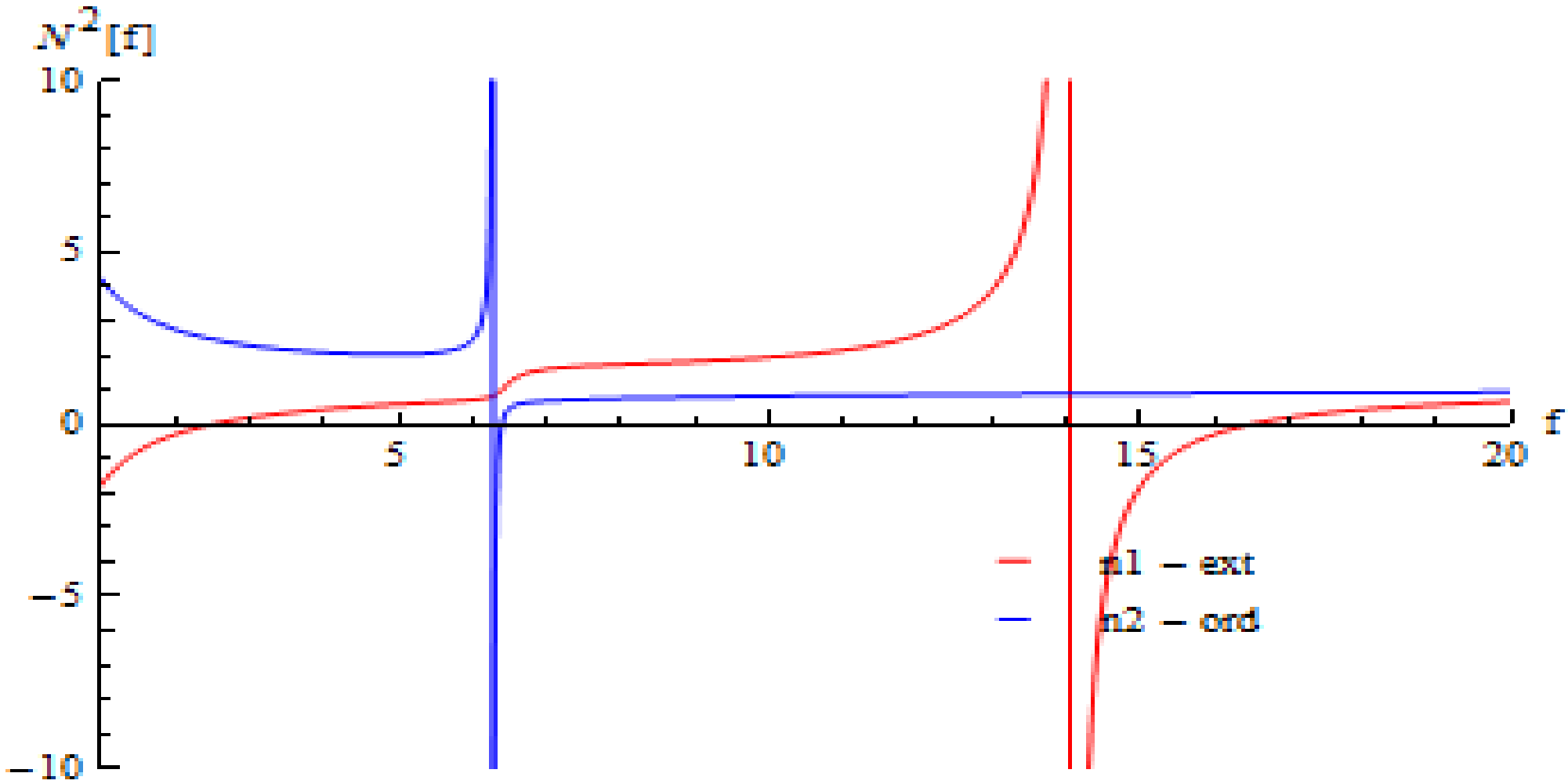
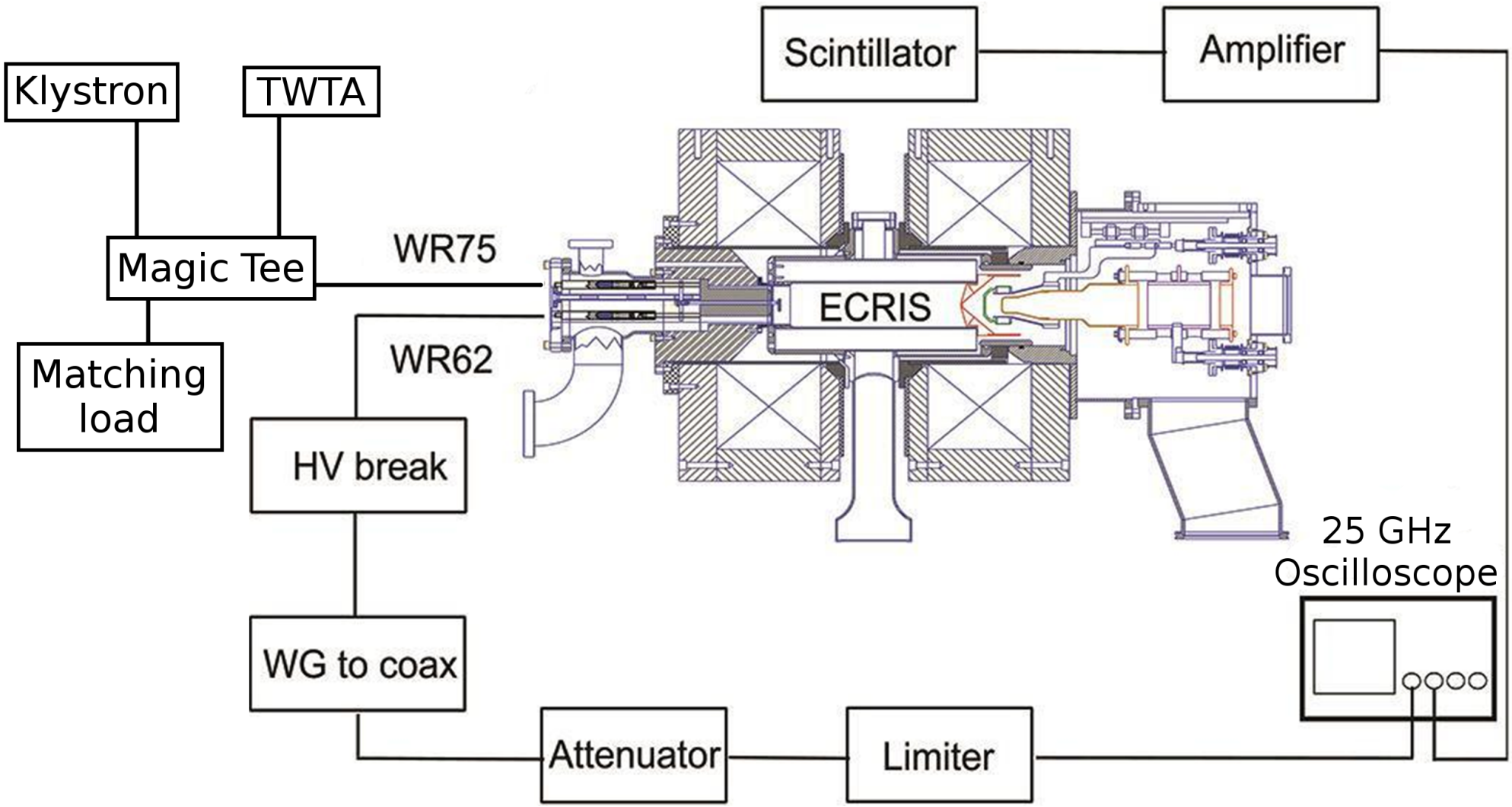
Slow extraordinary waves, low angles



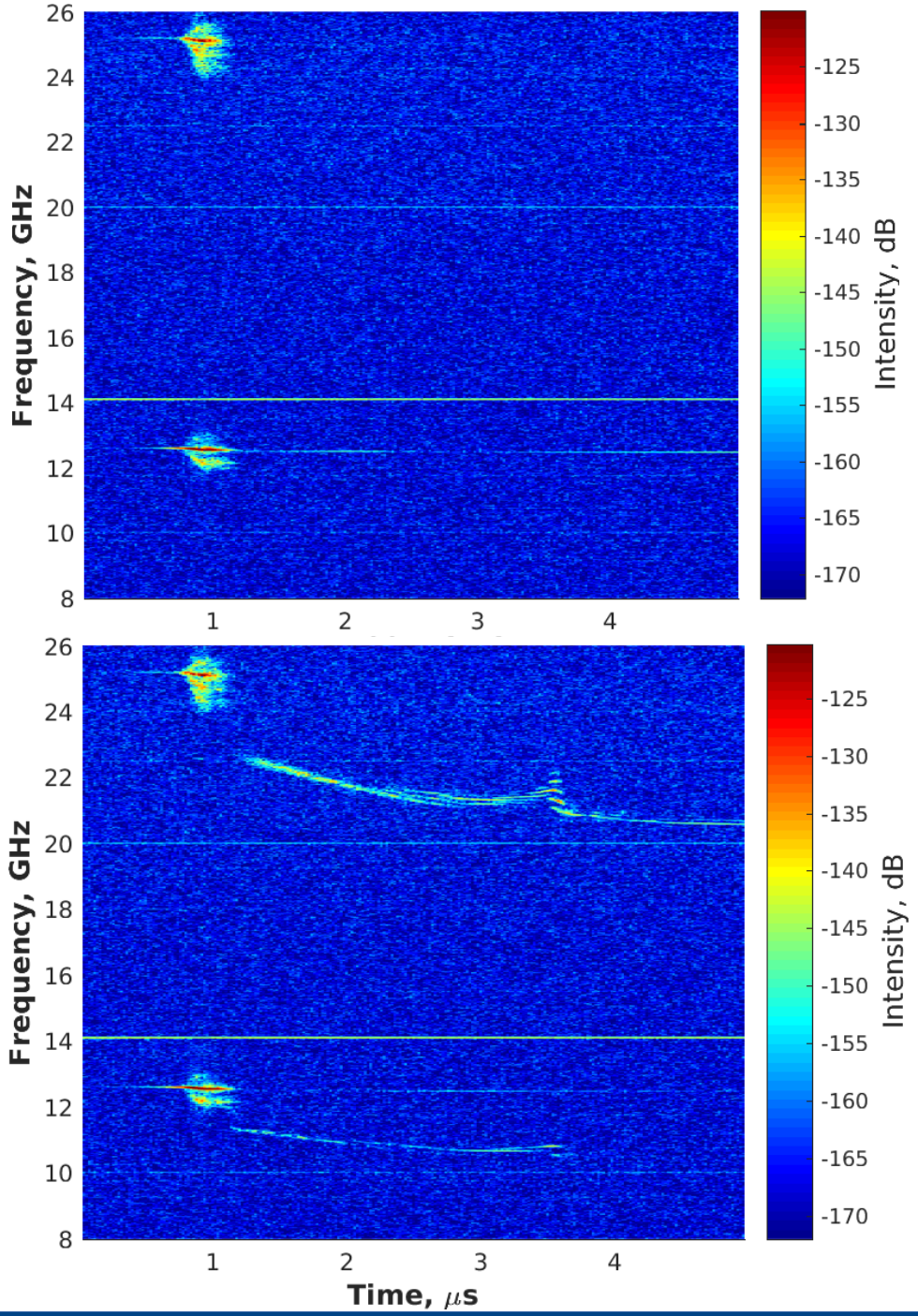
The most probable excited wave is the slow extraordinary Z-mode propagating quasi-longitudinally with respect to the external magnetic field. Such waves are excited with frequencies of $f_{pe}<f<f_{ce}$, which matches the experimental conditions. Moreover, it has been shown that the optimal emission frequency of the longitudinal Z-mode depends only weakly on f_{pe} (i.e. n_e) but is rather defined by the average energy of the electron population interacting with the wave.

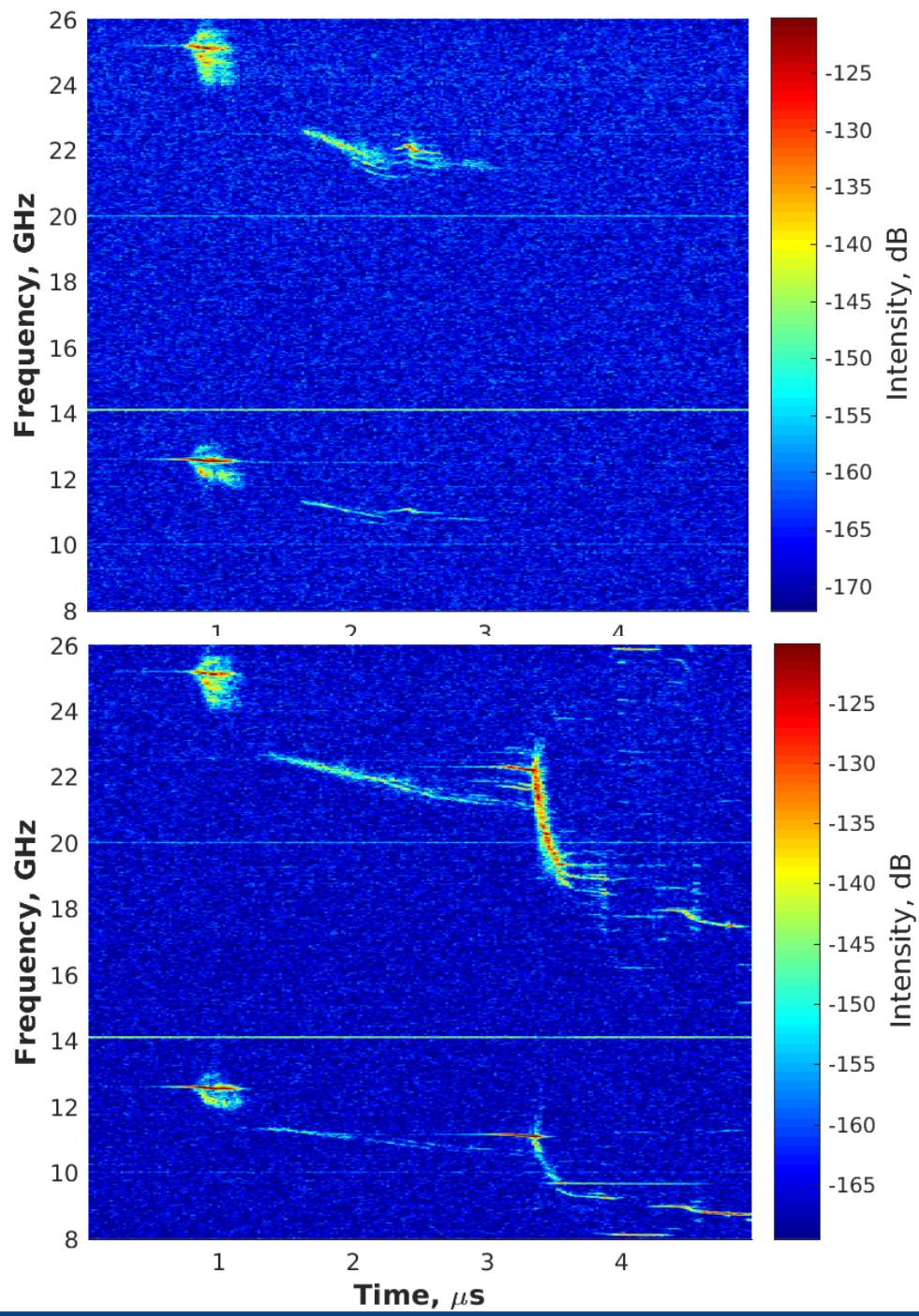
Improved scheme



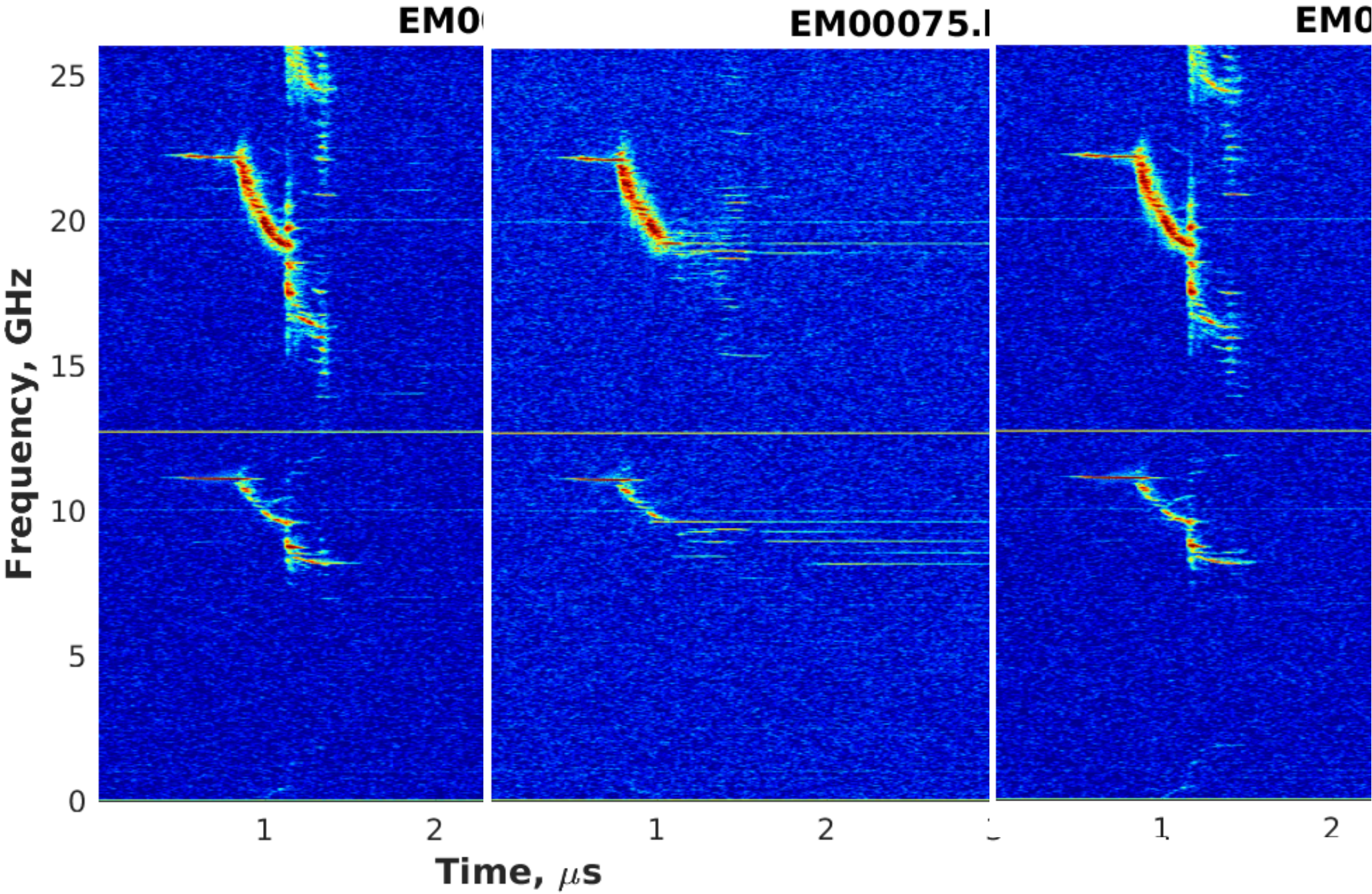
Frequency band of an acquisition system was expanded from 8-15 GHz to ~9-20 GHz (and even further, but with attenuating of higher frequencies). Fast oscilloscope with 25 GHz bandwidth was used for direct measurement of microwave emission waveform.

Broadband emission, 14 GHz heating

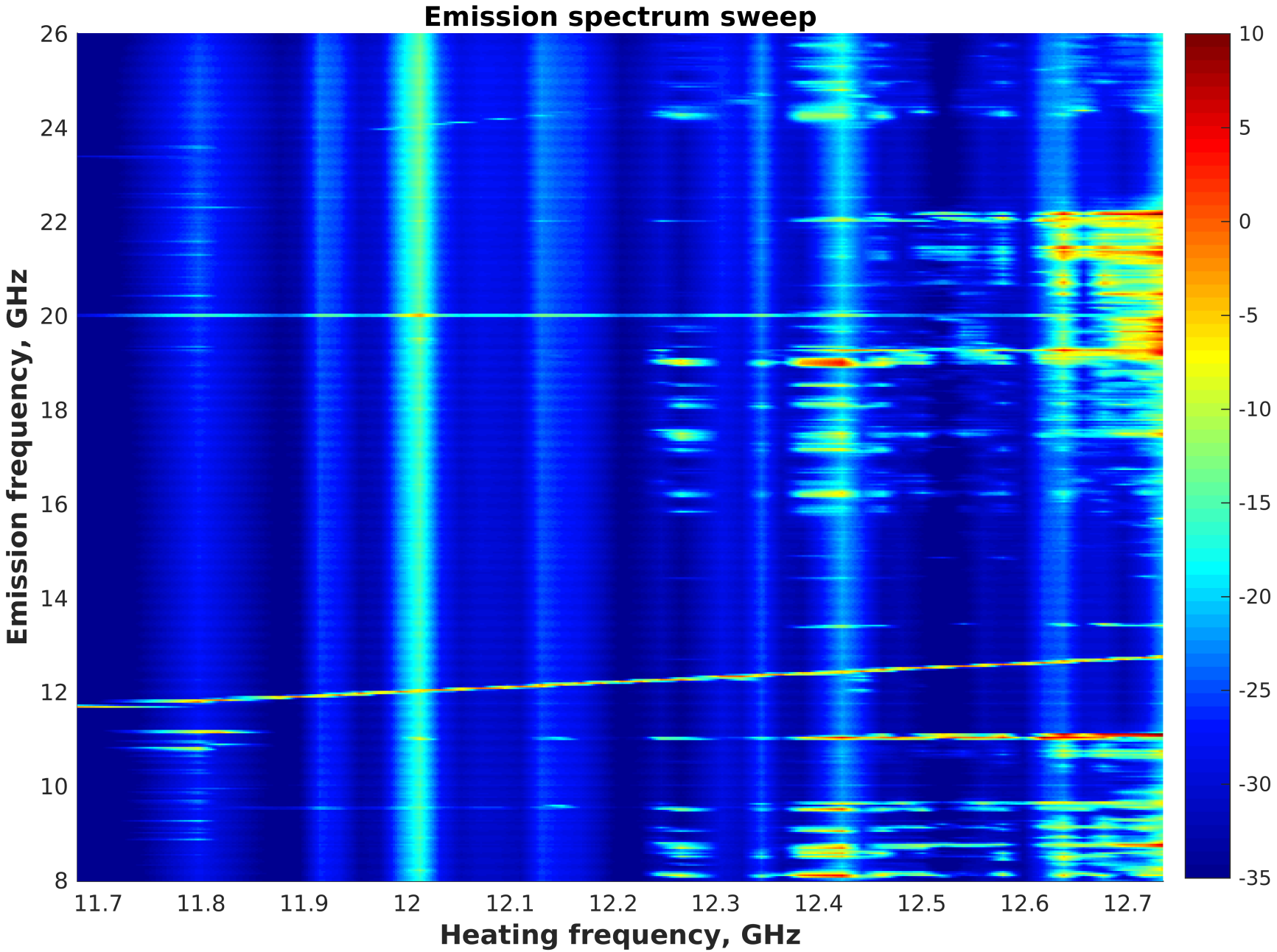




Broadband emission, TWTA heating, 12.75 GHz, ultimate settings (highest B-field, highest power)



Averaged emission spectrum dependence on heating frequency: TWTA 11.7-12.75 GHz, 200 W



More details on Wednesday, poster #WEPP43

Theoretical prediction of “CW” emission

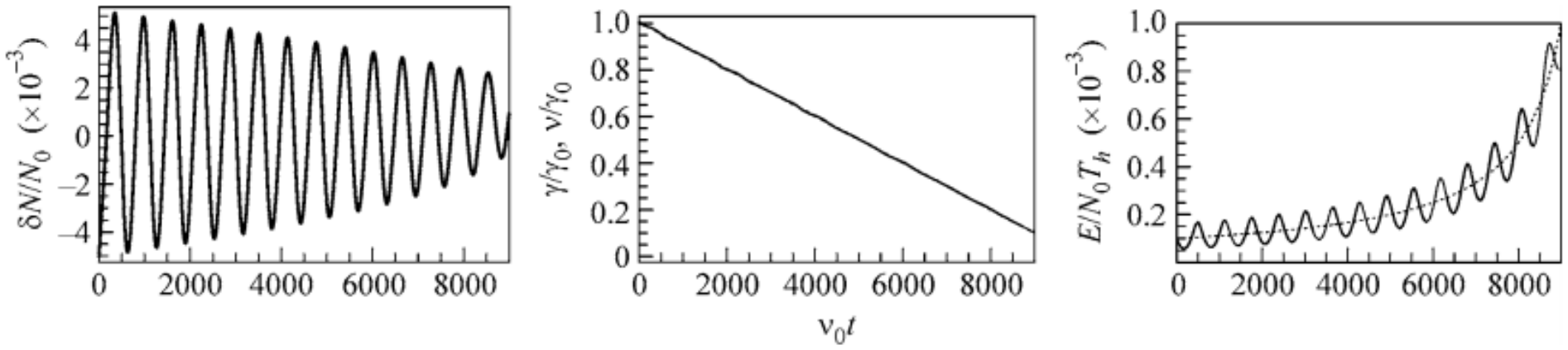
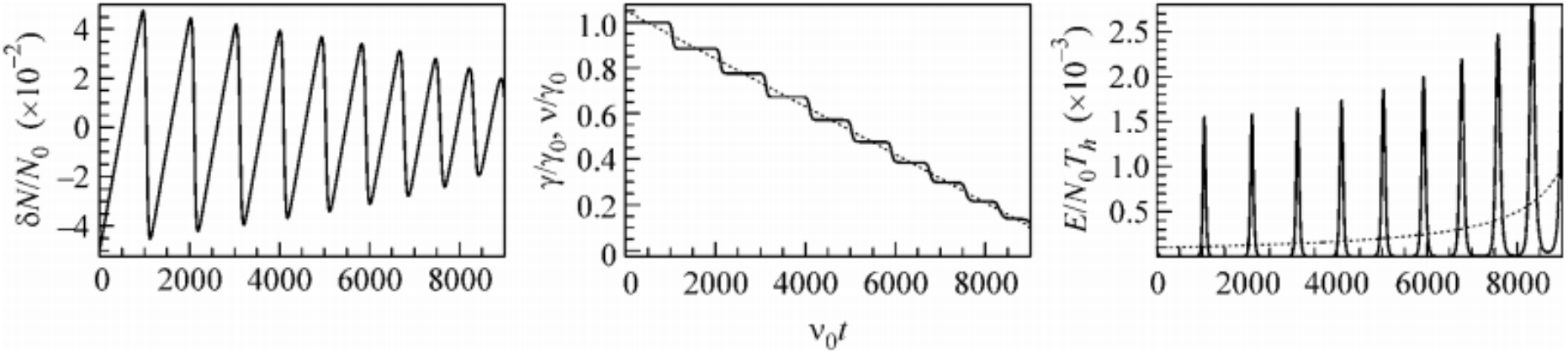
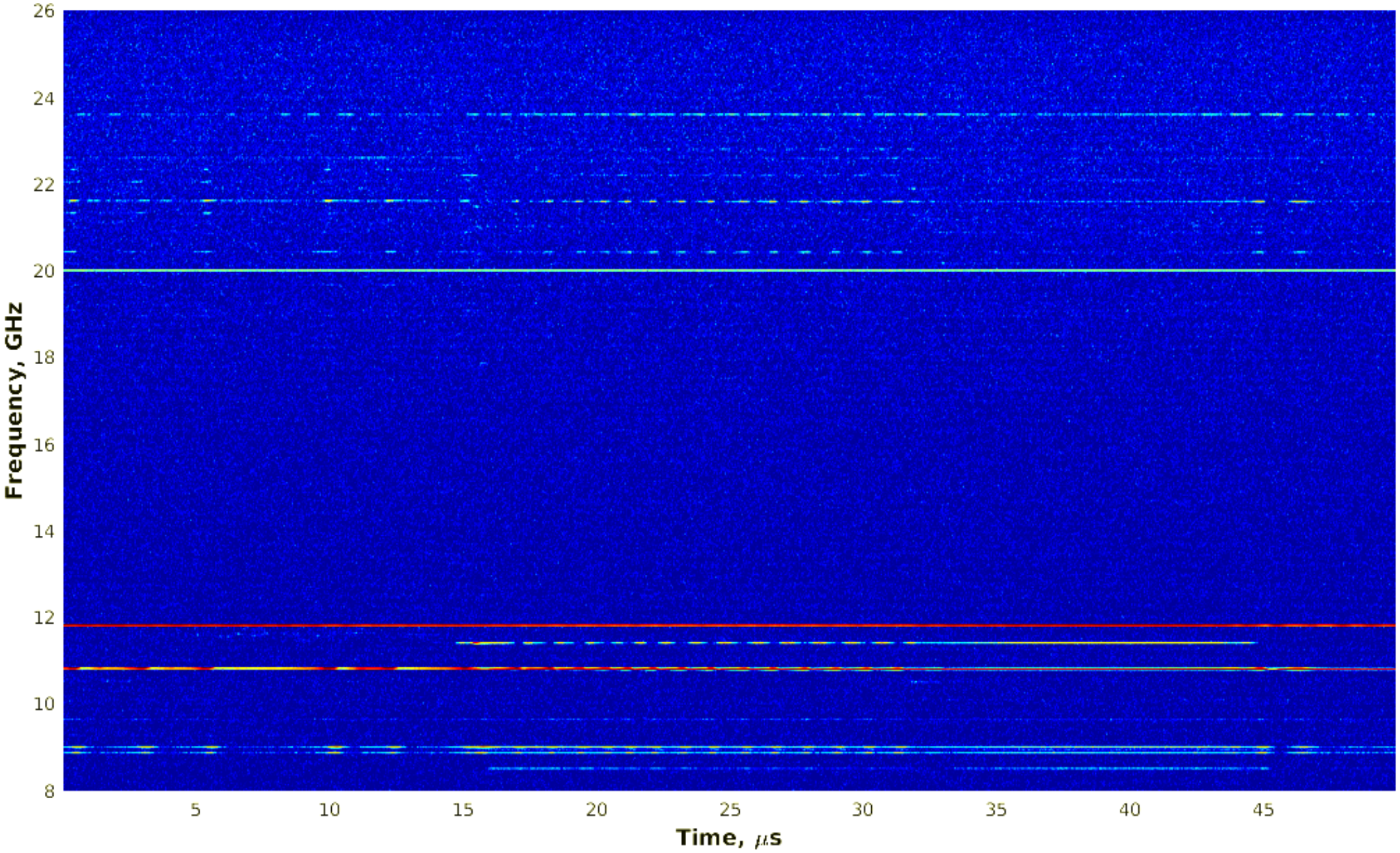


Fig. 1. Time dependence of (left panel) the deviation $\delta N = N - \bar{N}$ of the density of hot electrons from the average value, (middle panel, solid line) increment γ, (middle panel, dotted line) the decrement ν of the working mode of the maser, (right panel, solid line) the density of the electromagnetic energy E, and (right panel, dotted line) the average value $\bar{E}$ of this energy that are obtained for the linear regime by solving the system of Eqs. (1) and (2) with h = const, $\nu = \nu_0(1 - \nu^* t)$, $\nu_0/\gamma_0 = 1.005$, $\nu^*/\gamma_0 = 10^{-4}$, and $\varepsilon_0 = 0.99\nu^*/\gamma_0$.

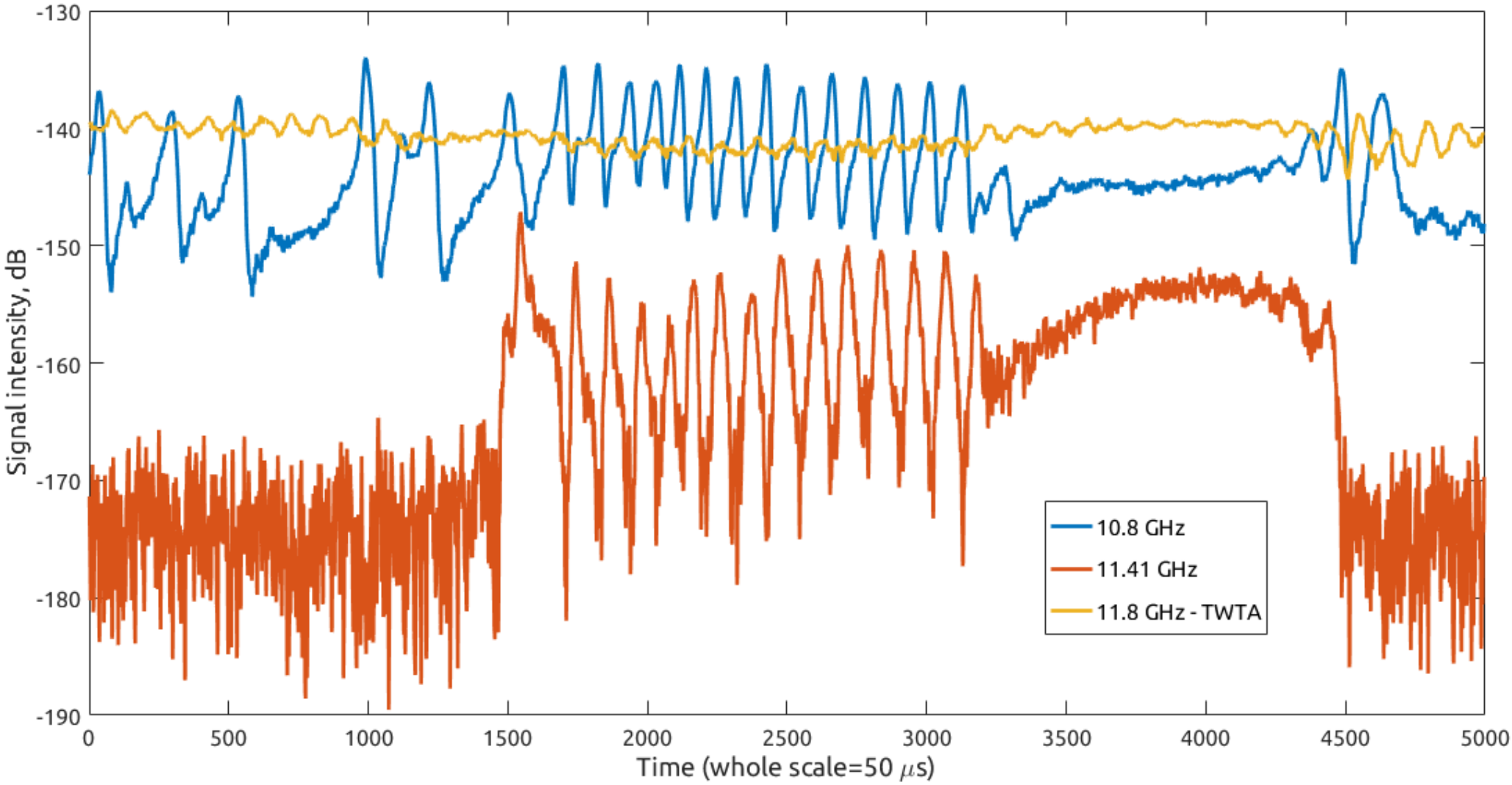


Shalashov et all, JETP Letters, 2006, Vol. 84, No. 6, pp. 314–319

CW/pulsed emission threshold

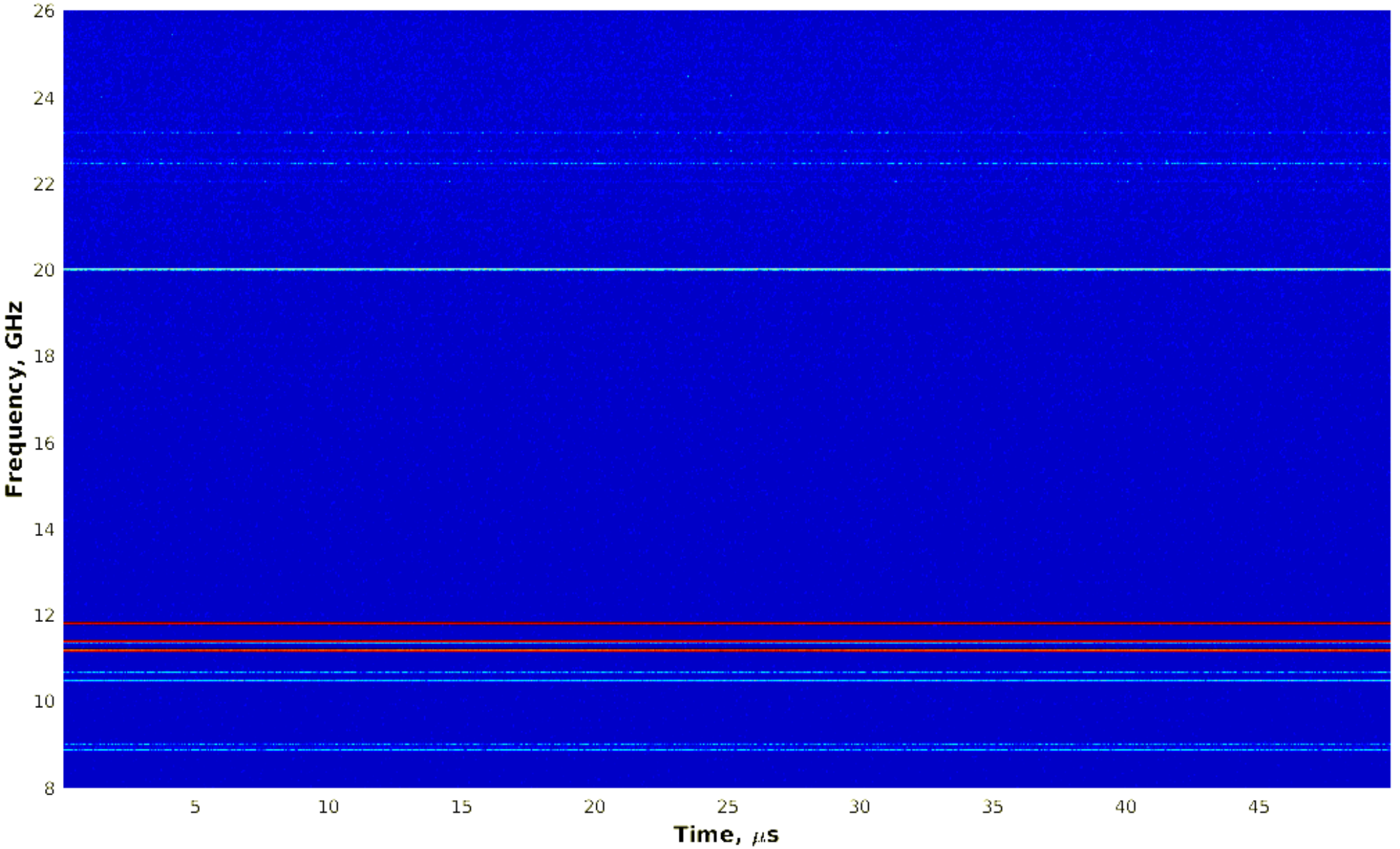


CW/pulsed emission threshold

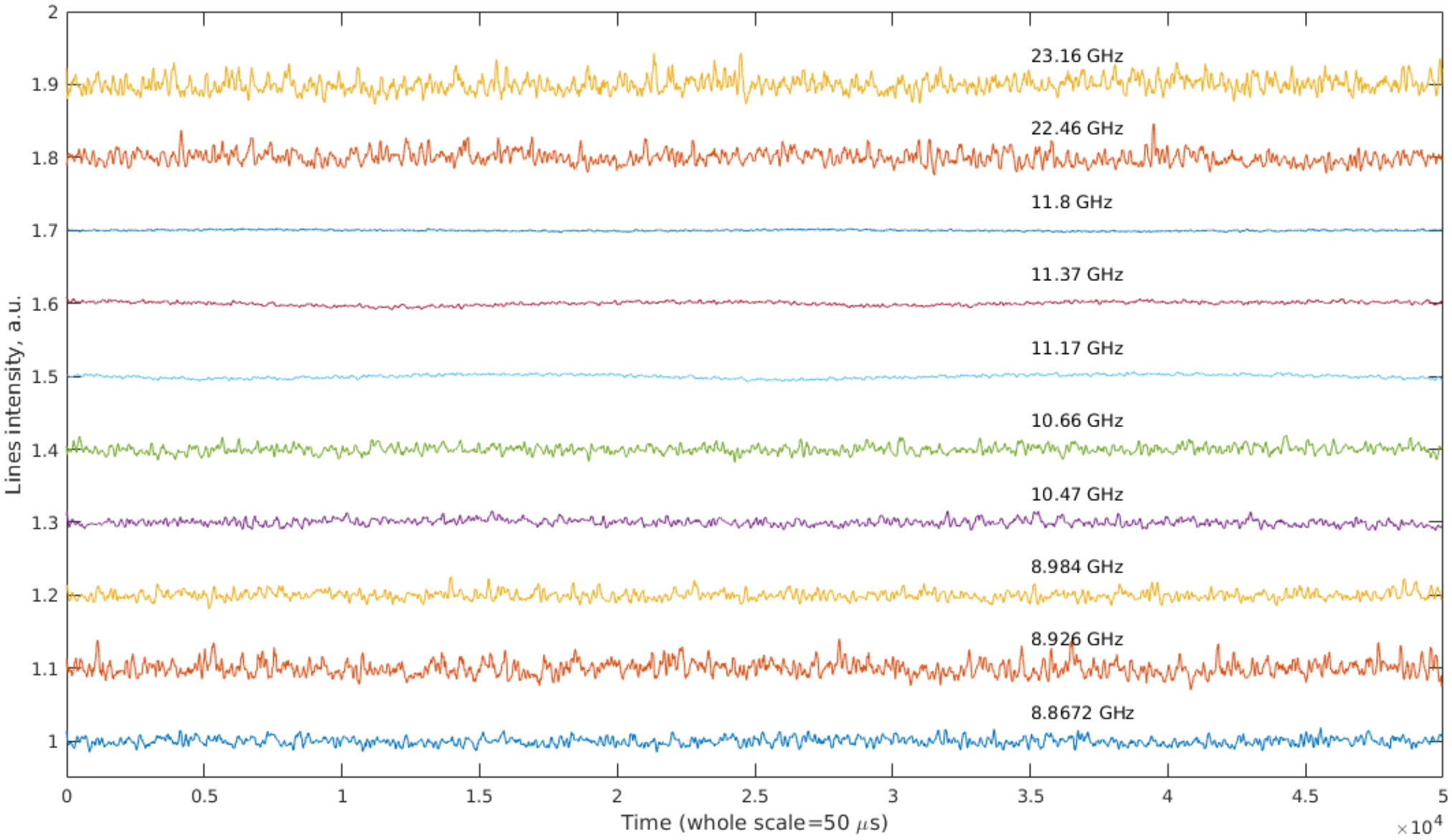


Threshold B-field value: the excitation of em-waves changes from non-linear pulsed mode to quasi-linear “CW”-mode forth and back!

Pure CW emission

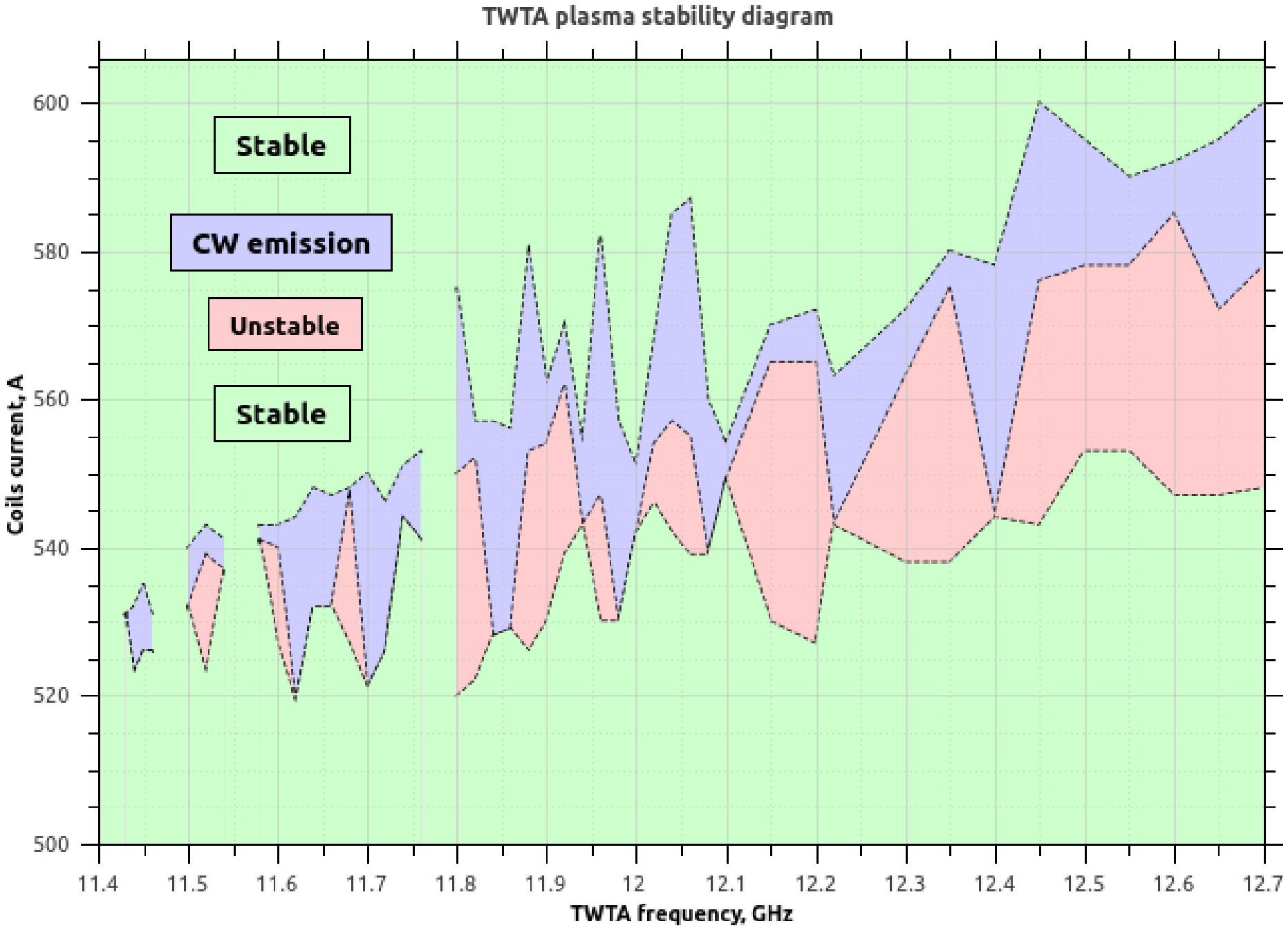


CW emission waveforms

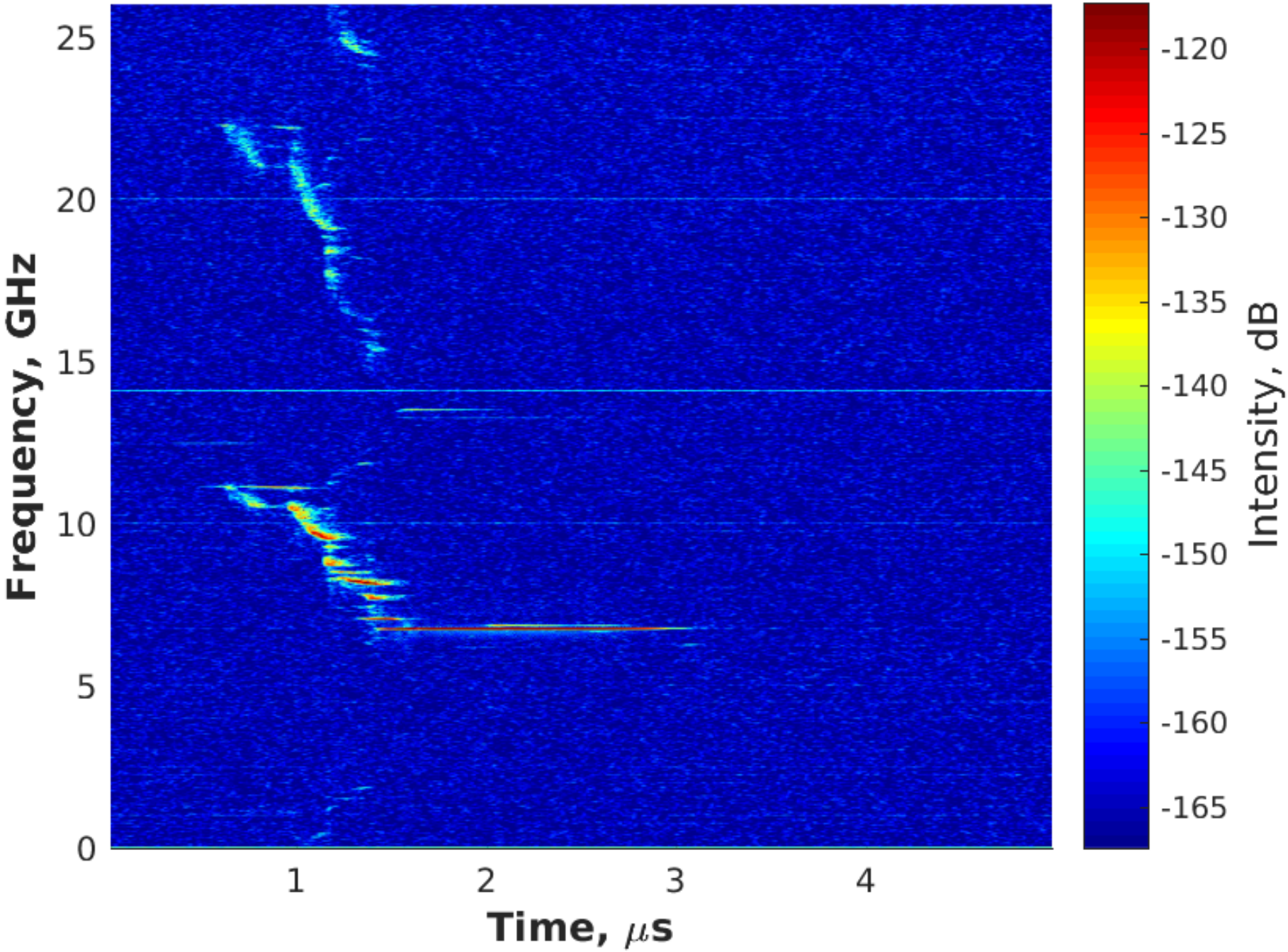


Signals are shifted and normalized

B-field – a main parameter to control CI



Open-space emission (no connection between scope and setup)



Conclusion

- Emission of em-waves in the frequency band 9-25 GHz has been observed
- Main emission frequencies have proven to be independent on heating frequency
- Quasi-linear regime of cyclotron instability accompanied by constant-wave electromagnetic emission has been experimentally observed for the first time
- Stable/unstable/CW zones have been found for set of frequencies
- Plasma emits even in the wider range of frequencies: 5 GHz < F < ??? (but obviously more than 25 GHz)

To be done:

- Mechanism of frequency doubling? (First/second harmonics? Double plasma resonance? …)
- CW emission frequencies dependence?
- Is it possible to improve ECRIS performance by driving it in a quasi-linear mode of CI?

Thank you!