Microwave Diagnostics of Dynamic Processes

A.L.Mikhaylov*, V.M.Belsky*, A.V.Rodionov*, S.V.Katin†, Yu.I.Orekhov†

* RFNC–VNIIEF, Sarov, Russia
† NIIIS, Nizhniy Novgorod, Russia

Summary: Microwave Doppler diagnostics of dynamic processes, which uses electromagnetic radiation with wavelength 3–4 orders longer than that of laser diagnostics, has some specific advantages. The paper presents description of the radiointerferometry bases, examples of typical experimental setups and experimental results, which couldn't be achieved, as a rule, by laser diagnostics.

Introduction

The physical bases of laser interferometry and microwave Doppler interferometry are the same. They include measurement of the Doppler shift of probing electromagnetic wavelength when electromagnetic wave is reflected from a moving surface.

However, using probing wavelengths 3–4 orders longer, microwave diagnostics has some specific advantages as compared to laser diagnostics [1], [2], [3], [4].

1. Measurement in radiotransparent media, which group is much more numerous than the group of optically transparent media.

2. For microwave diagnostics, surfaces of all practically-important gasdynamic jumps are mirror-reflecting.

3. Reflection of microwave radiation occurs from both jumps of density and jumps of dielectric permittivity (conductivity). It allows diagnostics of structural transformations inside a substance.

4. Wide spectral range of microwave devices provides the prospects for continuous radiometry.

Results and Discussion

The paper includes typical experimental setups for tests and their results, which demonstrate capabilities of microwave diagnostics of various dynamic processes when using a single equipment complex with probing wavelength $\lambda = 3.2$ mm, namely:

- investigation of shock-wave compressibility of substances,

- initiation and growth of detonation of condensed high explosives (HE),

- detonation propagation and detonation wave velocity changes inside HE sample,

- laminar combustion of heterogeneous HE,

- launching of liners and massive objects,

- shock-wave ionization of gases,

- dynamics of construction response under explosive loading,

- processes at low-velocity impact on HE.

As an example, Figure 1 presents a typical interferogram of shock wave propagation in radio transparent media (polystyrene), where the high-frequency component (wave velocity) is simultaneously recorded against the background of the low-frequency component of Doppler signal (particle velocity).

Figure 2 presents an interferogram of shock-wave initiation of detonation in plasticized TATB, where all characteristic stages of the process are recorded, including formation of stochastically distributed hot points and formation of detonation front inside HE.

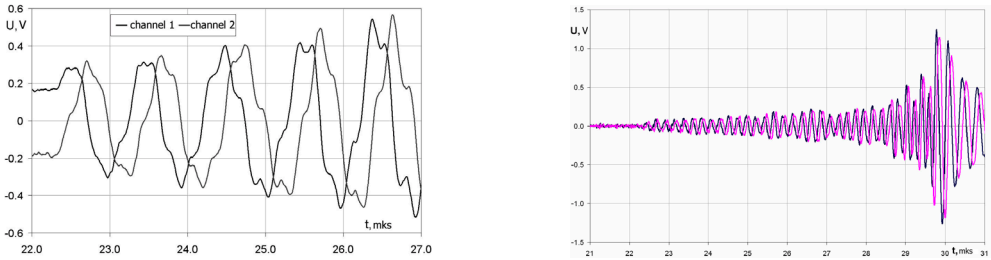

Figure 1. Typical recording:high-frequency shock wave component.

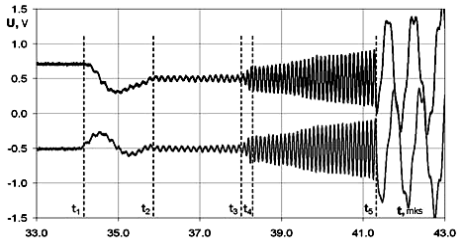

Figure 2, HE detonation initiation.

Conclusion

The examples from the abstract show that microwave Doppler continuous interferometry offers great promise for diagnostics of dynamic processes, including processes inside optically-opaque materials, which are unavailable for laser interferometry.

References

[1] A.L. Mikhaylov, V.I. Kostyukov, Yu.I. Orekhov, et al., “Some results of application of radiointerferometers with wavelengths of millimeter range in IPE RFNC-VNIIEF for study of gasdynamic processes”, in VII Khariton’s Scientific Readings (Sarov, Russia, 2005) pp. 649–655.

[2] .V.Rodionov, V.A.Kanakov, S.Yu.Lupov “Methods for processing results of radiointerferometric measurements of parameters of gasdynamic processes”, in VII Khariton’s Scientific Readings (Sarov, Russia, 2005) pp. 680–685.

[3] A.V.Rodionov, V.M.Belsky, A.L.Mikhaylov, et al., “Determination of detonation initiation depth by radio-wave method in plasticized HMX and TATB”, in XI Khariton’s Scientific Readings (Sarov, Russia, 2009) pp. 69–73.

[4] V.M.Belsky, A.L.Mikhaylov, A.V.Rodionov, A.A.Sedov “Microwave diagnostics of shock-wave and detonation processes”, in proc. “65 years anniversary of VNIIEF. Physics and technology of high density energy” V.2 (RFNC–VNIIEF Publishing House, Sarov, 2011) p. 268–297.

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