Influence of Aero-optical Transmission on Infrared Imaging Optical System in the Supersonic Flight

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PII: S1350-4495(14)00241-2
DOI: http://dx.doi.org/10.1016/j.infrared.2014.10.019
Reference: INFPHY 1677

To appear in: *Infrared Physics & Technology*

Received Date: 23 August 2014

Please cite this article as: L. Liu, W. Meng, Y. Li, X. Dai, Z. Zuo, Influence of Aero-optical Transmission on Infrared Imaging Optical System in the Supersonic Flight, *Infrared Physics & Technology* (2014), doi: http://dx.doi.org/10.1016/j.infrared.2014.10.019

Influence of Aero-optical Transmission on Infrared Imaging Optical System in the Supersonic Flight

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Abstract: Aero-optical transmission effect is becoming a crucial issue in the supersonic flight. In our study, the joint influences of the non-uniform aerodynamic flow field and the aerodynamically heated optical window on imaging quality of an airborne infrared optical system are investigated in depth. Both the laminar and turbulent viscous models are used in the simulation of aerodynamic flow because of their distinct influences on aero-optical transmission. On the basis of the computed density field, the ray tracing method is applied to calculate the point spread functions of the aerodynamic flow field and the aerodynamically heated window. The imaging quality is evaluated by using the point spread functions and modulation transfer functions. Experimental results show that the optical transmission through the aerodynamically heated window has a much severer influence on the imaging quality than that through the aerodynamic flow field.

Key words: Aero-optic, Ray-tracing method, Point spread function, imaging degradation

1. Introduction

When an aircraft with an infrared (IR) seeker flies at the high speed, ongoing interaction between the optical window and the incoming flow is so complex. In such a complexly varying flight environment, the aerodynamic flow induces large density gradients around the optical window. These gradients create refractive index variations so that the shock wave and the compressed flowfield around the window act as an aerodynamic lens with refraction index gradients [1-4]. Thus, the light wavefront distortion becomes random due to the turbulent flow with mixing of high and low density gases. This effect adversely affects the imaging quality of the airborne optical system. Specifically speaking, the mean flow field causes a boresight error and blurring, and the turbulence will cause blurring and very high-frequency jitter. The aero-optical environment around the IR imaging seeker in the supersonic flight is depicted in Fig. 1. And meanwhile because the aircraft transfers some of its kinetic energy into thermo of the flow surrounding the optical window, this effect often called aerodynamic heating causes the temperatures of the flow and optical window to rise rapidly [5]. The complex heat transfer between the flow and the optical window induces the non-uniform temperature distribution of the optical window that can severely distort the wavefront due to the thermo-optical effect. Therefore, the adverse influences of aero-optical transmission through aerodynamic flow field and aerodynamically heated window make remote and precise detection be a serious challenge, especially in high-mach flight.

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