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Advanced electric propulsion diagnostic tools at IOM

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Abstract

Recently, we have set up an Advanced Electric Propulsion Diagnostic (AEPD) platform [1], which allows for the in-situ measurement of a comprehensive set of thruster performance parameters. The platform utilizes a five-axis-movement system for precise positioning of the thruster with respect to the diagnostic heads. In the first setup (AEPD1) an energy-selective mass spectrometer (ESMS) and a miniaturized Faraday probe for ion beam characterization, a telemicroscope and a triangular laser head for measuring the erosion of mechanical parts, and a pyrometer for surface temperature measurements were integrated. The capabilities of the AEPD1 platform were demonstrated with two electric propulsion thrusters, a gridded ion thruster RIT 22 (Airbus Defence & Space, Germany, [1 3]) and a Hall effect thruster SPT 100D EM1 (EDB Fakel, Russia, [1,4]), in two different vacuum facilities.

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1. Introduction

Despite the successful verification of the potential of the AEPD1 platform, the tests revealed some severe problems. Firstly, the dimension of some of the diagnostic heads is in the order of the size of the exit plane of the tested thrusters. Thus, the interaction of diagnostic heads and energetic particle beam is rather large. Secondly, some of the diagnostic heads were placed inside vacuum sealed housings equipped with appropriate windows for safety reasons. Because of this, there is a certain risk that the window might break, when the housing is brought into the energetic particle beam. Breaking the window would result in a vacuum breakdown with the severe danger that the thruster or other devices might get damaged.

In order to overcome these problems, we are currently testing a new setup (AEPD2) [5,6], which utilizes modified (telemicroscope, triangular laser head), alternative (pyrometer) or additional diagnostic heads (thermocamera, retarding potential analyser) [7].

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The goal is to operate all diagnostic heads in vacuum. Doing so, we can reduce the dimension of the diagnostic heads considerably and eliminate the risk of a vacuum breakdown. Furthermore, the new diagnostic heads extend the variety of implemented measurement techniques (thermal imaging with thermocamera) or provide a low-cost alternative to existing devices (retarding potential analyser instead of the ESMS). Here, we describe the design of the diagnostic heads developed at the Leibniz-Institute of Surface Modification (IOM) and present the first experimental results, exemplary, with a gridded ion thruster RIT-μX.

The AEPD2 platform can also be equipped with an ExB probe, active thermal probe or Faraday probe developed, partly, by project partners. More information on these probes and their performance are given in References [5,6].

2. Experimental

2.1 Telemicroscope

The telemicroscope is used for high-resolution optical imaging. Taking images allows measuring, for instance, the erosion of mechanical parts [2,4]. The telemicroscope consists of a CCD camera, an extension tube and a photographic lens. The first setup of the telemicroscope was used a vacuum-sealed housing, because the CCD camera was not specified for in-vacuum operation, with a shutter and high-power LEDs for illumination. The setup worked fine [1,2,4] but the dimension was rather large: 120 mm in diameter and 500 mm in length.

In order to overcome the problems outlined above (size, vacuum breakdown), we decided to redesign the setup Fig. 1). First of all, the telemicroscope should be operated in-vacuum, even though it is still not specified for in-vacuum operation. Because of that, a smaller housing, which does not need to be vacuum-sealed, could be used. Furthermore, a smaller photographic lens is used. In order to select the best setup, calculations using simple optics and principal performance tests were done.

Imaging (see Fig. 2) can be described by the lens equation:

$$\frac{1}{f}=\frac{1}{s_1}+\frac{1}{s_2}$$

Here s_1 and s_2 denote the object distance and the image distance, respectively.

The magnification M can be calculated by

$$M=\frac{w_2}{w_1}=\frac{h_2}{h_1}=\frac{s_2}{s_1}$$

w_i and h_i are the width and height, respectively, of the object (i = 1) and image (i = 2).

First the case that the distance between object and camera is infinite, i.e. $s_1 = \infty$ is considered. In order to get a sharp image, the image plane must be placed at the focal point of the lens, i.e. $s_2 = f$.

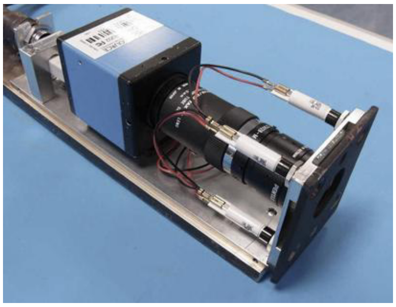

Fig. 1. New design of the telemicroscope setup with housing (without cover)

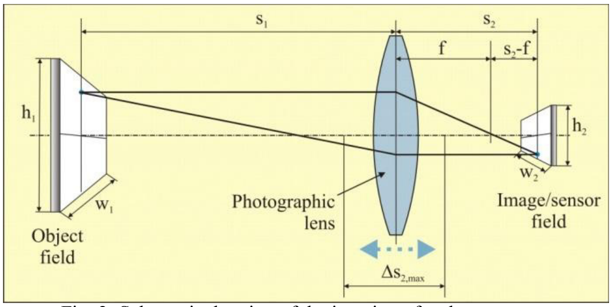

Fig. 2: Schematic drawing of the imaging of a photo camera (telemicroscope)

If the distance between object and camera is finite, the distance between lens and imaging plane must be increased by

$$\Delta s_2 = s_2 - f = \frac{1}{\frac{1}{f}-\frac{1}{s_1}} - f = \frac{f^2}{s_1 - f}$$