

Responses to the comments of the reviewers (February 12, 2015)

We would like to thank both reviewers for their thorough comments and questions. The valuable suggestions helped very much to improve the paper and to clarify some issues.

In the following, we give a point to point reply (in blue letters) to the comments of the reviewers. We also provide a draft of a revised version, where changes are written in green letters.

General comments reviewer #1:

Comment:

This paper continues the excellent series of articles that describe the GLORIA instrument and covers the aspects of the mechanical and thermal setup. These are critical aspects because the instrument operates in the difficult environment of an aircraft pod and also because the interferometer needs to be cooled for proper operation. Hence, this paper provides very important information. It does so brilliantly, and the subject is so thoroughly covered that one feels enough information is given to duplicate the experiment, a very rare quality.

Response:

We thank the reviewer for the favorable statement.

Specific comments:

These comments are really minor points that don't affect seriously the quality of the paper, but I think they should be addressed.

Page 10969 paragraph about vibrations does not make it clear if the requirement is driven by the performance of the FTS or by concerns for the aircraft safety.

We added two sentences for clearance accordingly:

"Also vibrations impact the instrument and the spectrometer optics. The vibration requirements are driven by the performance of the interferometer"

Page 10976, line 3: "the detectors full field of view (FOV) at this location" is an incorrect use of the term field of view, given that the scene is not imaged on the optical windows. Suggest instead to say "the optical beam at this location".

We changed the text: "...optical beam at this location..."

Page 10978, lines 19, 23, 27, 28 and also Figure 6. I think the use of the word "thread" is incorrect. The thread is the ridge or groove that winds around a screw. The correct word to use here is "leadscrew" (see:

<https://en.wikipedia.org/wiki/Leadscrew>).

We change to leadscrew: "... leadscrew..."

The velocity stability requirement of 5% (page 10968 line 24) is mentioned with a rather obscure reference of (Kimmig, 2001).

In fact the requirement is mainly based on experience. We will rephrase the sentence

"GLORIA uses time-equidistant sampling with post processing to account for velocity variations (Brault, 1996). In the ideal case, this technique can cope with velocity variations approaching 100 \%. In the reality, the optical paths of the infrared radiation and of the reference will not be completely identical and residual errors will arise. Based on unpublished experiences with MIPAS-STR, the goal for the velocity stability of the optical path difference measured

by the reference laser system is 5 % RMS which provides a reasonable trade-off between technical limitation and theoretical requirements.”

Page 10986 line 4 gives a measured 9% velocity stability: think it would be good to state the effect this had on the recorded atmospheric spectra, and if none maybe the 5% requirement was too pessimistic.

Indeed we can observe a small effect of the velocity variations on the recorded spectra. We will address this point in the text.

“The strong velocity variations around 220 Hz lead to so called “ghost”-signatures in the spectra (Learner et al., 1996; Kimmig, 2001). The ghost amplitude is up to 1.5 % and is mostly within noise level of nominal measurements. The impact of the ghost spectra on the retrieved temperature and trace gas profiles has not been quantified yet.”

Page 10969, line 18 and 5 places in Table 1: This is actually a typesetting comment. The symbol "g" is used here to denote the acceleration due to Earth gravity. To differentiate it from the SI symbol for gram, it should be typeset in italics, or maybe in a different font. (See https://en.wikipedia.org/wiki/Standard_gravity)

We changed typesetting for the symbol “g” to “standard italic”: “... *g* ...”

Technical corrections:

Only a few of these correct real mistakes. Most of these comments are actually suggestions.....

We accordingly included the 43 comments point by point. Please see the revised version of our manuscript.

Comments reviewer #2:

Comment:

Review of “The mechanical and thermal setup of the GLORIA spectrometer”, authors C. Piesch et al. The paper gives details of dedicated mechanics and cooling equipment for a novel imaging FT spectrometer, operated outside an aircraft. The paper clearly shows the subtle problems and solutions which definitely benefits from the previous experience gained with other airborne FT instruments. It becomes clear that the experience is worldwide unique and it is a good idea to share this knowledge by writing this paper.

Response:

We thank the reviewer for the favorable statement.

Comment:

Some revision could increase the quality of the paper.

Response:

We thank the reviewer for this comment which certainly will improve the paper. Our revisions shall give the paper the requested more precise focus and orientation. Detailed responses to the points are given below.

General comments:

The thermal and mechanical requirements are linked to the radiometric requirements. This link needs to be more established in the paper. For example, the requirement of 10% of DO 160C curve C should be linked to the required accuracy of the measured data. How must the mechanics be built that vibrations within the limitations do not cause errors outside the radiometric specifications? Another example is the 5% velocity error. This also needs a link to radiometric requirements of Gloria. The authors should rewrite the “2.1 Requirements” section establishing the link between radiometric and thermal/mechanical requirements.

The reviewer suggests establishing a direct and quantifiable link between accuracy of the measured science data and the thermal and mechanical requirements. This is a very difficult task far beyond the scope of this paper. Such an effort is typically undertaken in the definition phase of space instruments with large simulation studies. Here, we followed a more experimental approach: we knew from experience with the successful predecessor instruments where a safe zone for operation for an airborne FTS is and what conditions we have to expect. These values defined our requirements for the development of the GLORIA instrument. The 10% DO 160 C line is an example for this approach: we knew from measurements of vibrations on our old instruments that this is the vibration level we have to expect on the Geophysica aircraft. The requirement on 5% velocity stability is based on experiences with previous sensors. As the reviewer mentions, the main impact of velocity instability will be sampling jitter and thus phase ghosts in the spectra. GLORIA (and its predecessor instrument MIPAS-STR) use time-equidistant sampling with post processing to mitigate this problem. In the ideal case, this technique can cope with velocity variations up to 100%. In the real world, the optical paths of the infrared radiation and of the reference will not be completely identical and residual errors will arise. According to our experiences, the 5% development goal for the velocity stability provides a good trade-off between technical and theoretical requirements.

Further comments:

10968 Line 23-25: the requirement for opd stability of 5% rms is not clear. Gloria has detectors with very different properties from MIPAS-STR. What impact has a velocity error larger than 5% on the spectra, Shouldn't there be requirements regarding sampling jitter in frequency and intensity?

Indeed, we observe a small effect of the velocity variations on the final calibrated spectra.

We will address this point in the text: "The strong velocity variations around 220 Hz lead to ghost signatures in the spectra. The ghost amplitude is up to 1.5 % and is mostly within noise level of nominal measurements. The impact of the ghost spectra on the retrieved temperature and trace gas profiles has not been quantified yet and is subject of ongoing work.

10969 Line 5-6: is the pointing stability requirement independent of the observation mode?

The pointing stability requirements for the observation modes are slightly different. In the paper of Friedl-Vallon et al. (Instrument concept of the imaging Fourier transform spectrometer GLORIA, Atmos. Meas. Tech., 7, 3565-3577, doi:10.5194/amt-7-3565-2014, 2014) only the harder requirement (stability during CM) is mentioned (pointing stability 0,7 arcmin).

Is there a requirement regarding pointing jitter?

There is no specific requirement regarding pointing jitter. Pointing jitter must nonetheless remain within the pointing stability requirement. For details see Friedl-Vallon, F., et al. 2014.

Lines 7-21: It is not clear for which mechanical defined point the requirements are made. Is it where the instrument is attached to the aircraft or for any point in the mechanics of the instrument.

We add in the text: "These vibration values are given for the attachment points of the whole instrument at the carrier. However, these values are used as requirements for the spectrometer, too. In reality the vibrations may be damped or increased by the structure of the gimbal. Additionally, vibrations can be caused by airflow."

10970 Line 25-30: is there a more quantitative requirement for the reproducible temperature stability?

The quantitative requirement for temperature stability is given in Table 1: temperature < 220 K and temperature drift < 2 K/h

In chapter "2.1 requirements" are no heat load requirements:

The heat load depends on the environment conditions, the temperature, the convection and density of the air and the internal heat sources. The resulting temperatures in the interferometer are shown during ground operation (Figure 9) and flight (Fig. 15).

In the design phase, no requirement on heat load was specified, although efforts have been made to minimize the overall heat load. This thought was followed in all design considerations but without enforcing a quantitative requirement.

10976 Line 1-2: sentence has a problem

We changed the text: "The infrared radiation enters the optic module via an insulating double window assembly which hermetically seals the central body"

Line 10-12: unclear: what is oriented orthogonal to which optical beam

We reformulate the description: "The BSU consists (i) of a beam splitter with 104 mm diameter which is tilted 45° to the incoming beam and (ii) a separated compensation plate with 84 mm diameter which is oriented orthogonal to the reflected beam. Both, the wedged beam splitter substrate and the wedged compensation plate are made of KCl. The plates are fixed in a rigid aluminium structure by spring retainers."

10981 Line 15-16: the cooling should be caused by vaporization mainly instead of adiabatic cooling, please rephrase

We now use the word vaporization instead of adiabatic cooling.

10982 Line 16-18: Please explain how the data in table 3 were obtained

The total heat load is calculated from measuring the coolant weight and the gas flow at the exhaust of the cooling system. Additionally, the result is verified by measuring the temperature drift without coolant. The internal heat loads generated by electric components are measured via the power consumption. The distribution shown in table 3 has been established with a series of laboratory measurements with different operation configurations.

We added the following explanation: "The total heat load is calculated based on the measured coolant weight and the gas flow at the exhaust of the cooling system. Additionally, the result is verified by measuring the temperature drift without coolant. The distribution shown in Table 3 has been established with a series of laboratory measurements with different operation configurations."

10986 Line 3-14: the radiometric impact of the observed velocity variations should be shown or summarized (with reference to other paper if published).

We can observe a small radiometric impact of the velocity variations on the recorded spectra. This has not been published yet since a detailed analysis of the effect is still outstanding. We, however will address this point in the text:

"The strong velocity variations around 220 Hz lead to so called "ghost"-signatures in the spectra (Learner et al., 1996; Kimmig, 2001). The ghost amplitude is up to 1.5 % and is mostly within noise level of nominal measurements. The impact of the ghost spectra on the retrieved temperature and trace gas profiles has not been quantified yet."