Laboratory measurements of the complex refractive index of Saharan dust aerosol

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1 Abstract

High quality aerosol optical properties are essential if satellite measurements are to be used to quantify the atmospheric effects of aerosols. The optical properties can be directly used to quantify the radiative effects of the aerosols on the atmosphere. The latest results from a set of laboratory measurements of the optical properties of Saharan dust aerosols representative of those found in the atmosphere are shown. The extinction cross section spectra has been determined by IR Fourier transform spectrometry. The size distributions of the aerosol are measured directly by two instruments; a sequential mobility particle sizer and counter and an aerodynamic particle sizer. Conversion of the extinction cross section spectra to refractive index is then accomplished by an novel inversion technique using Mie theory.

2 Motivation

The project has a number of end aims; to allow further assessment of the role of mineral aerosols in atmospheric chemistry and radiative transfer, and to improve satellite retrievals of aerosols.

Uncertainties in satellite instruments retrieval schemes of aerosol parameters are currently limited by our knowledge of the optical properties of several aerosol types including Saharan dust. Thus high quality reference measurements of the optical properties will add value to satellite instruments (for example ATSR/2, AATSR, MIPAS, MSG, HIRDLS, TOMS, MERIS).

3 Method

The extinction cross section is related to the optical transmission by:

$$T(\lambda) = \exp^{-\beta(\lambda)x}$$

Where:

T Transmission.
β Volume extinction coefficient.
x Measurement path length.

The volume extinction coefficient is given by:

$$\beta(\lambda) = \int_0^\infty \sigma_{ext}(r, m, \lambda) n(r) dr$$

Where:

σ_{ext}	Extinction coefficient.
r	Particle radii.
m	Particle complex refractive index.
λ	Wavelength.
$n(r)dr$	Number of particles between radii r and $r + dr$.

Hence to obtain the extinction coefficient, σ_{ext} we require the measurements of the optical transmission, T as well as the particle distribution, $n(r)$.

4 Samples

The main sample used durring this work is a wind blown sediment sample from Cape Verde. Due to the geography this sample is representive of the wind transported dust from the Sarahan region. This sample was first dried before dispersal in the experiment.

5 Experimental setup

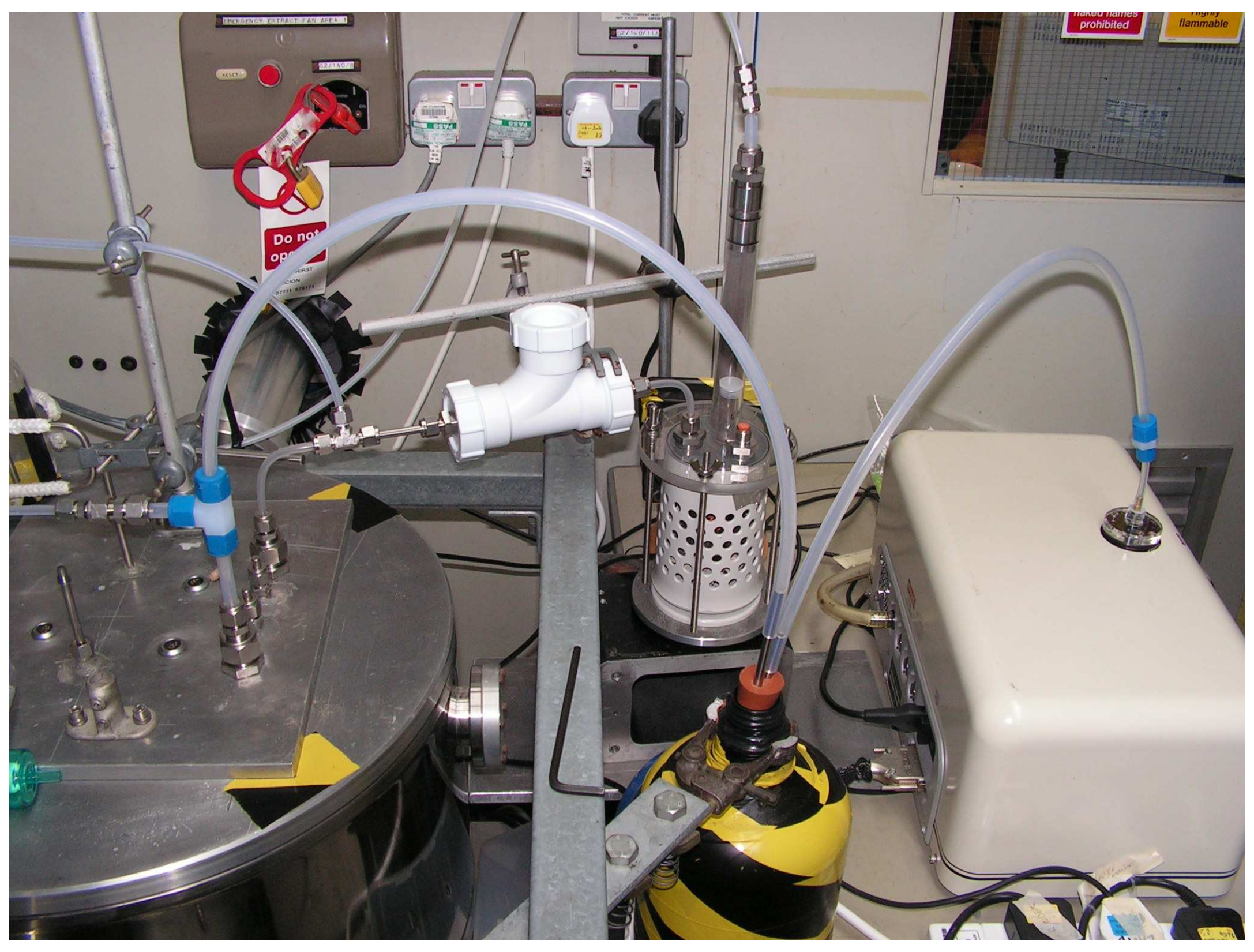

Figure 1 Photograph of the experiment. left; the aerosol cell middle; the disperser right; the Aerosizer.

Figure 1 and 2 outlines the basic configuration of the experiments undertaken. The aerosol is generated from a powder sample and then introduced to the small aerosol cell. The aerosol cell has optical windows fitted, allowing the aerosol absorption to be measured via the Fourier Transform Spectrometer, FTS. Particle size distribution of the aerosol is then determined and the aerosol then exhausted into a fume cupboard. The configuration also included a water bath to allow the relative humidity to be controlled from 0 to 50%.

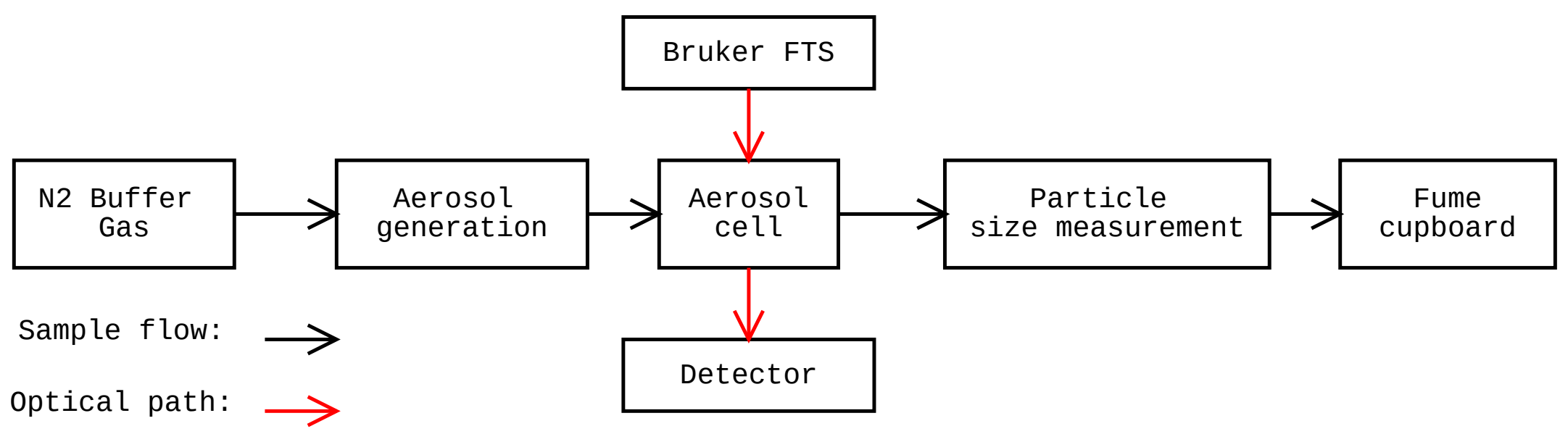

Figure 2 Simplified diagram of experimental configuration.

5.1 Aerosol Generation

Generation of mineral aerosols with a suitably high number density was difficult. Our commercial disperser could not generate sufficiently high number densities, so we designed our own disperser. A photograph of the aerosol produced is shown in figure 3 a stable aerosol can be produced at high number densities over many hours (see figure 3 right). N_2 was used as the carrier gas.

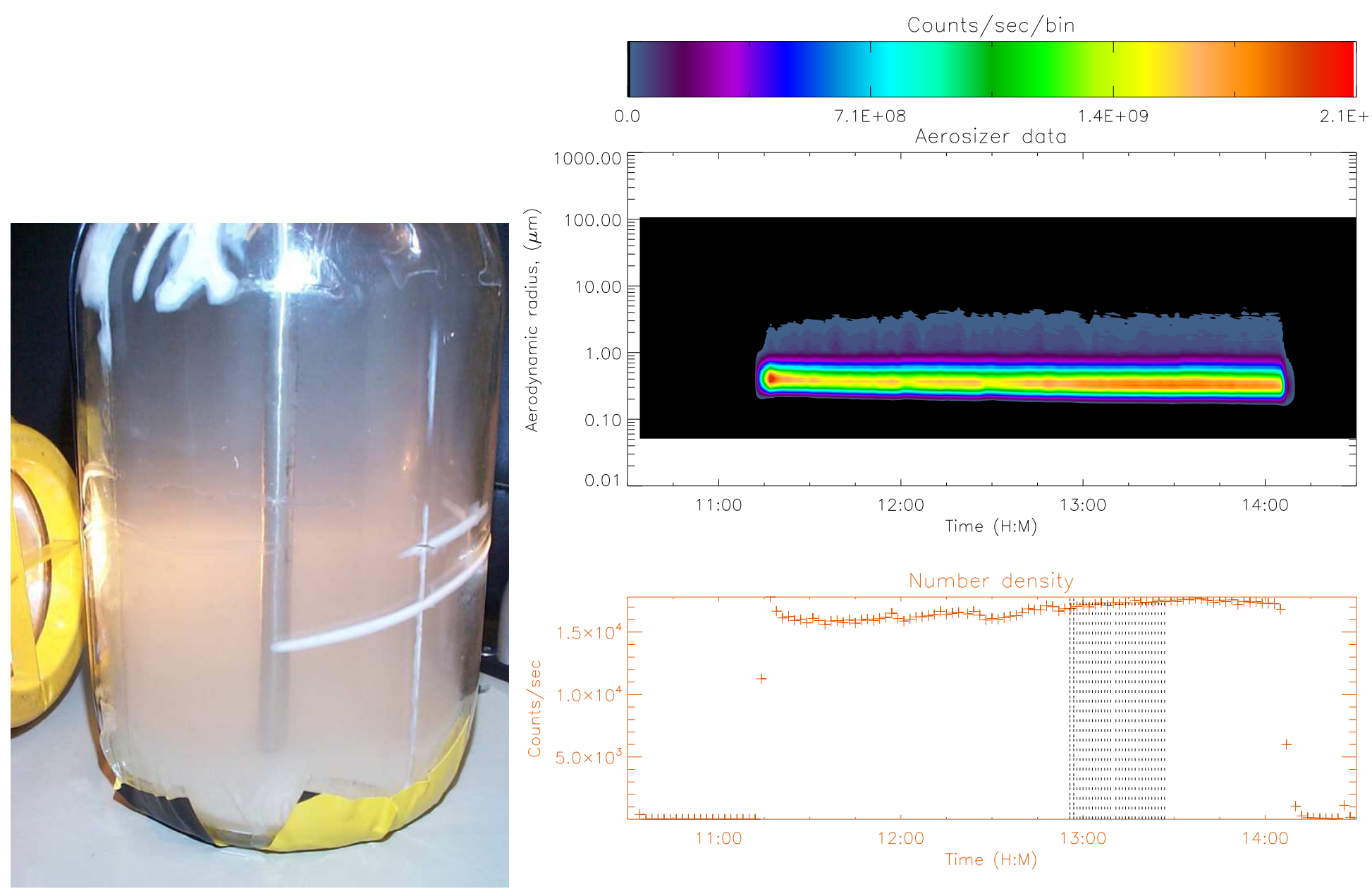

Figure 3 Left: A typical high number density aerosol generated using the aerosol disperser. Right: Example of a measured size distribution, time evolution, vertical dotted lines represent when spectra was measured

5.2 Aerosol Cell

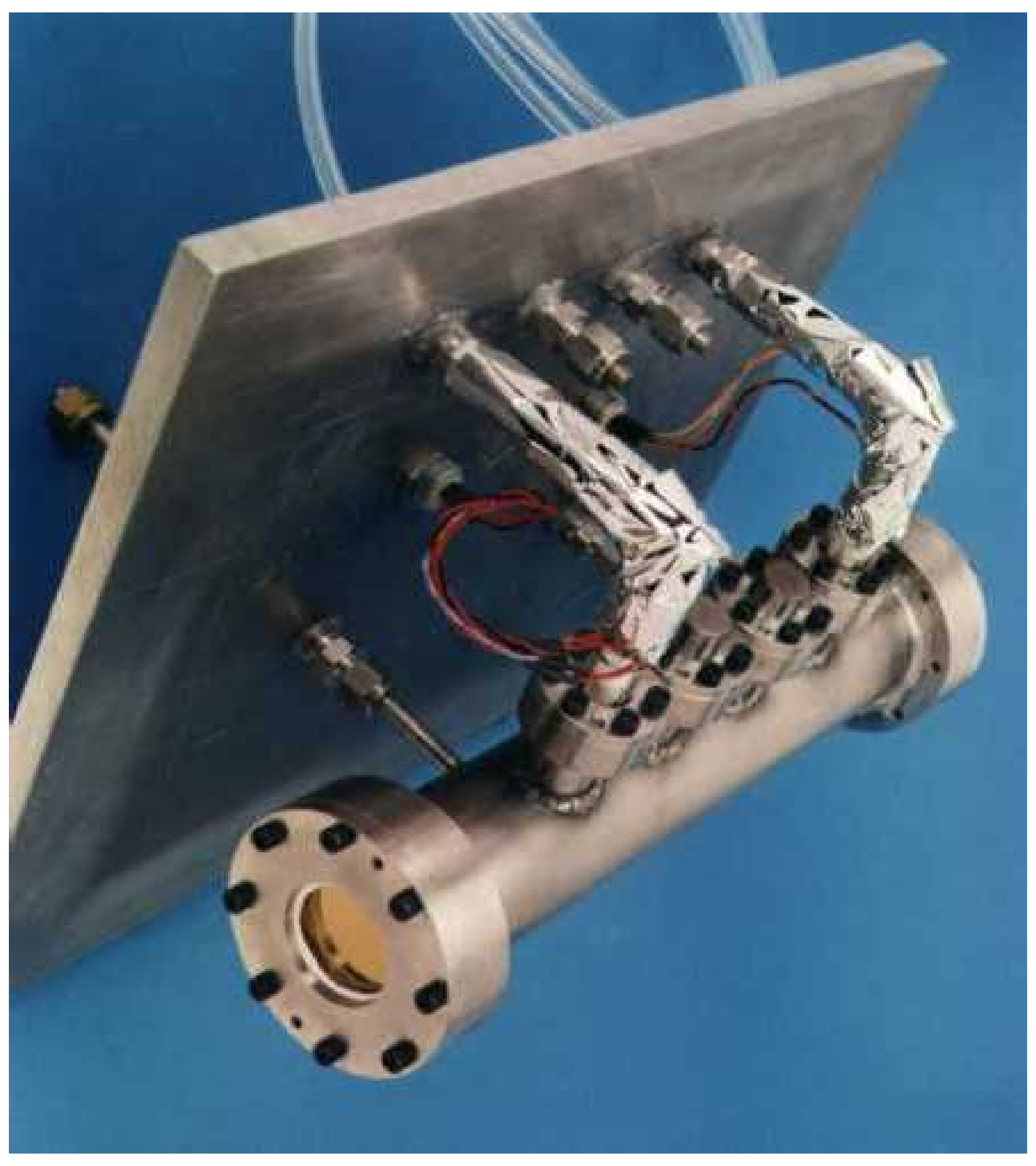

Figure 4 The small aerosol cell.

The MSF small aerosol cell has an optical path length of 30 cm. Spectral intensity measurements are made using a Bruker FTS. Measurements of the detected intensity are obtained with and without the aerosol to calculate the transmission spectrum, $T(\lambda)$.

5.3 Size distribution measurements

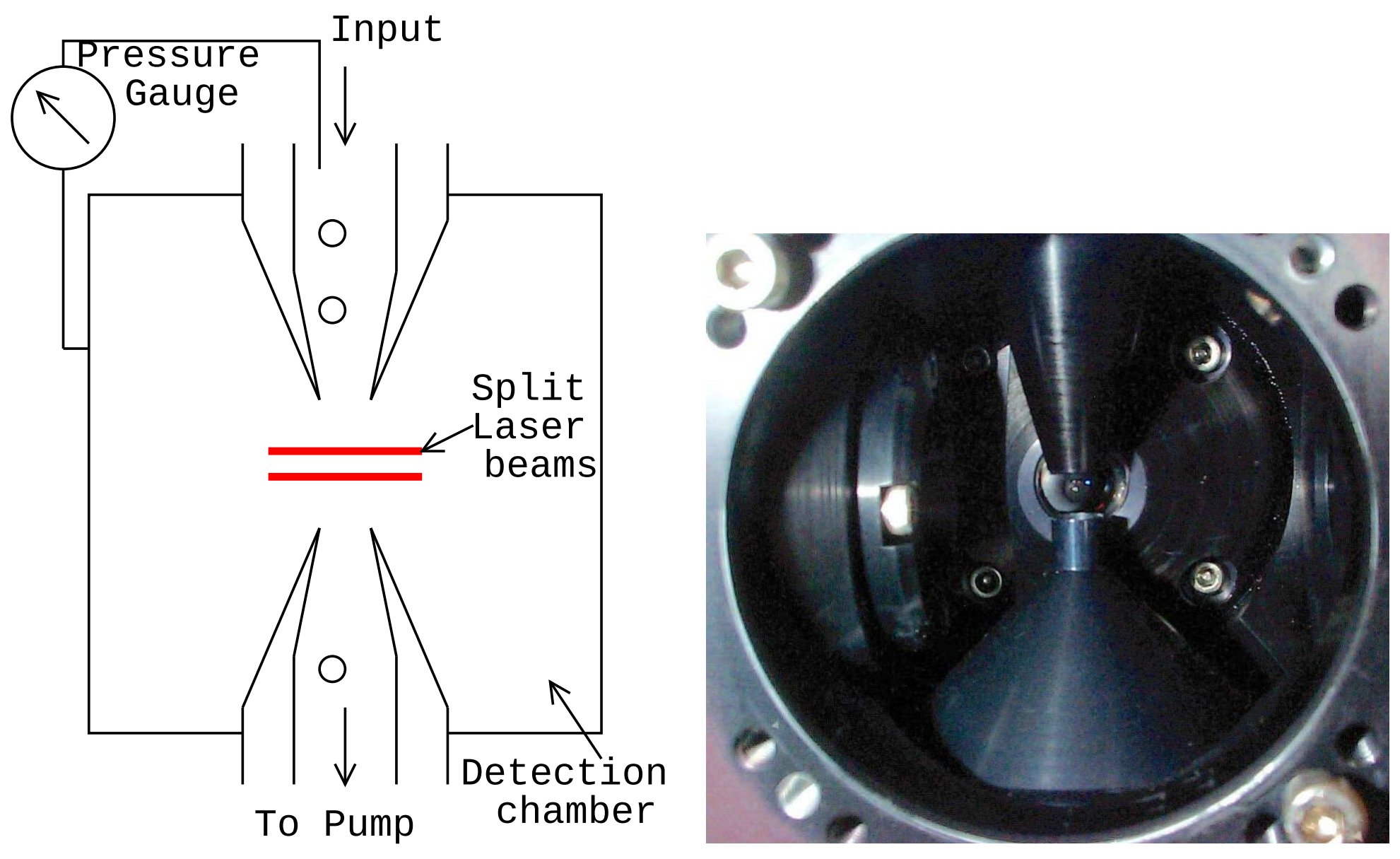

Figure 5 The Aerosizer.

The particle size distribution is measured by an Aerosizer LD manufactured by Amherst Process Instruments. It is able to measure the particles aerodynamic diameter in the range 0.5μm, to 700 μm. The technique is independent of the particles refractive index, but we do need to know the particles density. This particle sizer is available to other users of the MSF on request (depending on the chemical compatibility of the Aerosizer LD to the aerosol).

6 Results

Figure 3 shows the measured aerosol size distribution, for the spectra shown in figure 6. The lower size limit of the Aerosizer LD is around 0.5 μm and is a function of the instruments Photo Multipliers Tube (PMT) voltage. Unfornatly the particles were of a smaller size, and the instrument was only sensitive to the tail of the distribution.

7 Refractive index

The method describe by Thomas [3][2] has been used to retrieval the refractive index of the aerosol from the measured absorption spectra. An example fit is shown in figure 6, complete with the associated refractive index in figure 7.

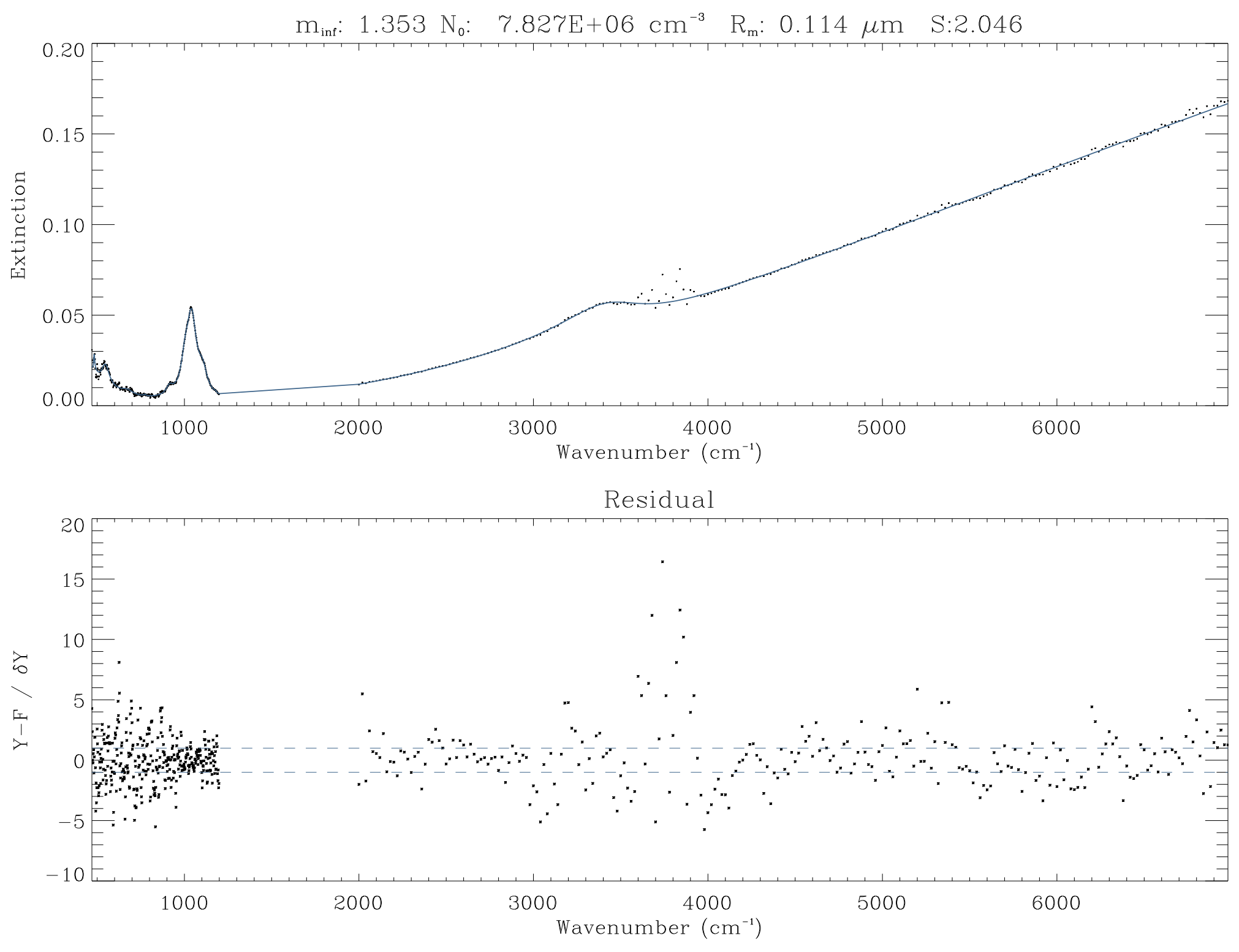

Figure 6 Top: Measured spectra (dots) and fitted spectra (lines). Bottom: residual.

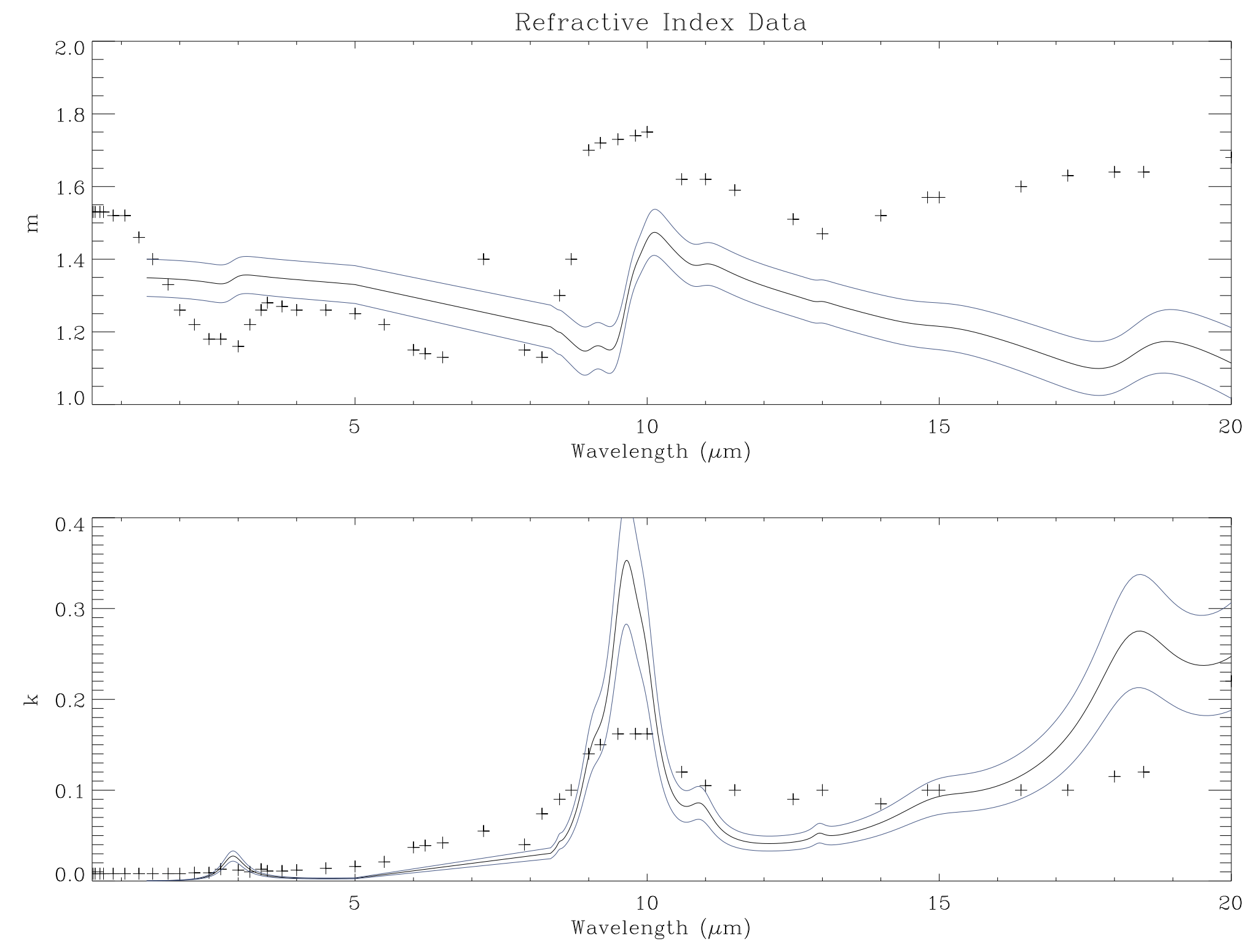

Figure 7 Inverted complex refractive index of the Cape Verde sample (black line). Blue line indicates estimated uncertainties. Crosses show the existing published data [1]

8 Conclusions

The preliminarily results shown in figure 7 show the diffrances between current data and this new data set. Significant diffrances exist in the optical properties. In the following months these results will be finalised and published.

References

[1] Eric P. Shettle and Robert W. Fenn. Models for the aerosols of the lower atmosphere and the effects of humitdity variations on their optical properties. Technical Report AFGL-TR-79-0214, Air Force Geophysics Laboratory, September 1979.

[2] G. E. Thomas, R. G. Grainger, and R. A. McPheat. A new method of retrieving aerosol optical properties form IR extinction measurements. *COSMAS annual meeting Bristol*, 2004.

[3] Gareth E. Thomas, Stephen F. Bass, Roy G. Grainger, and Alyn Lambert. Retrieval of aerosol refractive index from extinction spectra with a damped harmonic-oscillator band model. *APPLIED OPTICS*, 2005.