Diffraction and line shape of Fourier-transform spectrometers

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The effect of diffraction on the instrument line shape of a Fourier-transform spectrometer is studied with an analytical line-shape model. The expression for the instrument line shape of a diffracted point source is obtained. A simple condition on the throughput of the instrument is derived under which diffraction is negligible when compared with the field-of-view-induced line shape. The effect of diffraction is illustrated and compared for various instruments. © 2003 Optical Society of America

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1. Introduction

There is always a need to improve the accuracy of spaceborne Fourier-transform spectrometers (FTSs). Currently the radiometric accuracy is even specified with respect to the ideal instrument line shape (ILS): the cardinal sine. Even the slightest deviation in the line shape may lead to significant error in forward models. With the advent of ILS removal algorithms, it is furthermore important to properly model the instrument response to correct it adequately.

The analytic line-shape model allows the effect of diffraction on the ILS of a FTS to be derived, at least for simple cases, such as a perfectly collimated ideal point source. This simplistic analysis has the benefit of allowing a comparison of diffraction on the ILS with other line-shape contributions, such as the beam divergence and interferogram truncation.

An important part of this work was done by Salonen et al. This paper presents a more formal derivation in terms of the radiant intensity in the interferometer and shows that a radiometric factor, cos θ, was missing in prior expressions. The condition that ensures that diffraction is negligible is expressed only as a function of the optical throughput and the minimal wave number measured. Finally a comparison of the effect of diffraction, beam divergence, and interferogram truncation on the line shape is presented. In principle this analysis is valid for any amplitude-splitting interferometer that sweeps the optical-path difference in the time domain.

First the radiant intensity after a diffracting aperture illuminated by a plane wave is calculated. This gives the radiant intensity produced in an interferometer by an ideal point source whose perfectly collimated beam is diffracted by the aperture stop. This calculation is done with the angular spectrum of plane waves formalism. The obtained radiant intensity is then used to feed the analytic line-shape model so that the ILS of a diffracted point source is obtained.

These diffracted line shapes are then compared with the contribution of beam divergence. This allows the derivation of a simple rule of thumb for quickly determining whether diffraction is important in the line shape of a given spectrometer. The condition is related to the one presented by Salonen et al. but is expressed as a function of throughput only and does not need the intervention of the FTS signal-to-noise ratio.

Finally the contributions of diffraction, beam divergence, and interferogram truncation to the line shape are compared graphically for some specific FTSs.

2. Radiant Intensity Resulting from a Diffracting Aperture

The angular spectrum of plane waves relates, by a two-dimensional Fourier transform, a monochromatic field \( U(x, y, z) \) to its spatial frequencies in a...
plane perpendicular to the \( z \) axis that is taken as the interferometer’s optical axis:

\[
U(x, y, 0) = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} A(u, v) \exp[i(ux + vy)] \, du \, dv,
\]

(1)

\[
A(u, v) = \frac{1}{(2\pi)^2} \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} U(x, y, 0) \exp[-i(ux + vy)] \, dx \, dy,
\]

(2)

where \( u \) and \( v \) are the spatial frequencies in two orthogonal directions corresponding to \( x \) and \( y \), respectively, and \( A(u, v) \) is the amplitude of the corresponding spectral component.

The definitions \( u = k_o p, v = k_o q \), and \( a(p, q) = k_o^2 A(k_o p, k_o q) \) are convenient since they allow the wave number \( k_o \) of the monochromatic wave to be used explicitly. The bidirectional relation between \( U(x, y, 0) \) and \( a(p, q) \) can thus be written as

\[
U(x, y, 0) = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} a(p, q) \exp[ik_o(px + qy)] \, dp \, dq,
\]

(3)

\[
a(p, q) = \frac{k_o^2}{(2\pi)^2} \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} U(x, y, 0) \exp[-ik_o(px + qy)] \, dx \, dy.
\]

(4)

The field in the half-space delimited by the aperture is then

\[
U(x, y, z) = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} a(p, q) \exp[ik_o(px + qy + mz)] \, dp \, dq.
\]

(5)

It therefore appears that \( a(p, q) \) is the amplitude of a plane monochromatic wave propagating in a direction specified by \( (p, q, m) \). The variables \( p, q, \) and \( m \) are the projections of a unit vector specifying the propagation direction on the \( x, y, \) and \( z \) axes, respectively. Since \( m, p, \) and \( q \) are orthogonal projections of a unit vector, \( p^2 + q^2 + m^2 = 1 \).

The geometry of interferometers leads to the use of off-axis and azimuthal angles \( \theta \) and \( \phi \) of a spherical coordinate system instead of \( p, q, \) and \( m \). The systems are related by

\[
p = \sin \theta \cos \phi,
q = \sin \theta \sin \phi,
m = \cos \theta.
\]

(6)

From Parseval’s theorem\(^{10} \) the power of a signal can be evaluated either in the spatial or the frequency domain. In this case

\[
\int_{-\infty}^{\infty} \int_{-\infty}^{\infty} \left| U(x, y, 0) \right|^2 \, dx \, dy
= \frac{(2\pi)^2}{k^2_o} \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} \left| a(p, q) \right|^2 \, dp \, dq.
\]

(7)

Changing the coordinates for the right-hand term to our spherical system yields

\[
\int_{-\infty}^{\infty} \int_{-\infty}^{\infty} \left| U(x, y, 0) \right|^2 \, dx \, dy
= \frac{(2\pi)^2}{k^2_o} \int_0^{2\pi} \int_0^\pi \left| a(\theta, \phi) \right|^2 \cos \theta \sin \theta \, d\theta \, d\phi.
\]

(8)

This integral of the power over the angles accepted in the interferometer has exactly the form needed for the analytic line-shape model.\(^{4–7} \) All the terms of the integrand before the solid angle element \( d\theta d\phi \) in Eq. (8) are in fact the expression of the radiant intensity distribution after the diffracting plane.

Equation (8) shows that knowledge of \( |a(p, q)|^2 \) is sufficient to perform the integral over \( \phi \) and then immediately deduct the contribution of the diffraction to the ILS by replacing \( \theta \) by \( \arccos(\sigma/\sigma_o) \), as allowed by the analytic line-shape model.\(^5 \)

In this expression \( \sigma_o \) is the true wave number of the monochromatic radiation entering the instrument, and \( \sigma \) is the apparent wave-number scale that is normalized by the true wave number of the monochromatic radiation entering the instrument. This normalization is useful since most of the line-shape contributions are near \( \sigma/\sigma_o = 1 \).

In Eq. (8) the factor \( \cos \theta \), which is not present in the paper by Salonen et al.,\(^8 \) represents a reduction in the effective aperture area by a factor \( \cos \theta \) for plane waves emanating from the aperture at an angle.

3. ILS of a Point Source Diffracted by a Circular Aperture

A simple case will now be studied. It is assumed that an on-axis point source is perfectly collimated in the interferometer. The pupil in the interferometric domain is thus filled by a plane wave. The field incident on the aperture can then be modeled as an infinite plane wave that will be filtered by the aperture of radius \( r_o \). The field incident on the aperture is therefore described as

\[
U(x, y, z) = E_o \exp[ikz]
\]

(9)

In a plane of constant \( z \) the field is uniform both in phase and amplitude, as represented by the complex
variable $E_o$. The plane of the aperture is chosen to be $z = 0$.

The field in the aperture being known, it is possible to calculate $a(p, q)$ after the aperture

$$a(p, q) = \frac{k_o^2}{(2\pi)^2} \int_0^{2\pi} \int_0^{\pi} E_o \exp[-ik_or(p \cos \phi + q \sin \phi)] r dr d\phi,$$

(10)

where Eq. (4) has been put in polar coordinates, and the field is assumed to be zero on the walls of the aperture. Equation (10) is easily evaluated and gives

$$a(p, q) = \frac{k_o^2 E_o}{(2\pi)^2} \frac{2J_1(k_or \sqrt{p^2 + q^2})}{k_or \sqrt{p^2 + q^2}}$$

$$= \frac{k_o^2 E_o}{(2\pi)^2} \frac{2J_1(k_or \sin \theta)}{k_or \sin \theta},$$

(11)

where $J_1(x)$ is the first-order Bessel function of the first kind.

Equation (11) is the very classical result for the diffraction of a plane wave by a circular hole. The so-called Fraunhofer diffraction pattern is visible at infinity, where the angles ($\theta, \phi$) are resolved in positions.

According to Eq. (8) the ILS of a FTS is directly obtained from the angular distribution of the power:

$$I = \frac{(2\pi)^2}{k_o^2} \int_0^{2\pi} \int_0^{\pi} \left| \frac{k_o^2 E_o}{(2\pi)^2} \frac{2J_1(k_or \sin \theta)}{k_or \sin \theta} \right|^2 \cos \theta \sin \theta \, d\theta d\phi.$$  

(12)

Because the diffraction pattern is circularly symmetric, the integral on $\phi$ follows immediately:

$$I = 2\pi |E_o|^2 \frac{k_o^2}{(2\pi)^2} \int_0^{\pi/2} 4J_1^2(k_or \sin \theta) \cos \theta \sin \theta \, d\theta.$$  

(13)

This expression is the integral of the intensity per unit solid angle around $\theta$. From the analytic line-shape model\textsuperscript{4,5} the line shape is found by replacing $\theta$ with $\arccos(\sigma/\sigma_0)$ in the terms before $\sin \theta d\theta$. After the substitution is done and the peak value is normalized to one, the ILS is simply

$$\text{ILS}_a(\sigma, \sigma_0) = \frac{4J_1^2(2\pi r_o \sigma_0 \sqrt{1 - (\sigma/\sigma_0)^2}) \sigma}{(2\pi r_o \sigma_0 \sqrt{1 - (\sigma/\sigma_0)^2})^2 \sigma_0},$$

(14)

where the line shape depends only on the normalized wave number $\sigma/\sigma_0$ and a normalized parameter $r_o \sigma_0$, representing the number of wavelengths in the aperture radius.

The contribution of the diffraction to the ILS is shown in Fig. 1. It can be seen that the $[2J_1(x)/x]^2$
diffraction pattern is nonlinearly mapped on the wave-number scale. As always there is no contribution higher than \( \sigma \), because it is impossible to create more optical-path difference than that experienced by the on-axis rays. The diffraction contribution to the ILS is therefore asymmetric.

The result obtained here is similar to that presented by Salonen et al.\(^8\) The extra \( \cos \theta \) that translates into \( \sigma / \sigma_o \) comes from the formal consideration of the radiant intensity in the interferometer.

4. Diffraction Versus Finite Field-of-View Effect

Of course the diffraction and the integral over the field of view (FOV) (off-axis effect) must be considered simultaneously to obtain the correct total ILS. Before doing this, it is, however, possible to assume that both contributions to the line shape may be, at least at first order, combined by a local convolution in the same way that other ILS contributions are usually merged.

Instead of actually calculating the convolution, this section concentrates on comparing the widths of both contributions to the line shape. A condition will then be derived to establish when it is justifiable to neglect diffraction in FTSs.

In this approach it is also assumed that the effect of the finite FOV has already been matched to the contribution of the truncation of the interferogram, as discussed by Brault.\(^12\)

The first zero of the function \( J_1(x) / x \) is at \( x = 3.83 \). It is thus possible to calculate the wave number \( \sigma \) at which the diffracted line shape falls to zero:

\[
2 \pi r_o \sigma_o \sqrt{1 - \left( \frac{\sigma}{\sigma_o} \right)^2} = 3.83, \quad (15)
\]

so that

\[
\frac{\sigma}{\sigma_o} = \left[ 1 - \left( \frac{3.83}{2 \pi r_o \sigma_o} \right)^2 \right]^0.5. \quad (16)
\]

Because \( r_o \sigma_o \) is usually large, the approximation

\[
\frac{\sigma}{\sigma_o} \approx 1 - \frac{1}{2} \left( \frac{3.83}{2 \pi r_o \sigma_o} \right)^2 \quad (17)
\]

is justifiable. The width of the diffraction contribution to the ILS is therefore

\[
\Delta(\sigma / \sigma_o)_{\text{distant}} \approx \frac{1}{2} \left( \frac{3.83}{2 \pi r_o \sigma_o} \right)^2 \quad (18)
\]

The width of the boxcar arising when the FOV is circular and centered is well known to be\(^12\)–\(^14\)

\[
\Delta(\sigma / \sigma_o)_{\text{FOV}} = 1 - \cos \theta_{\text{max}} \approx \frac{\theta_{\text{max}}^2}{2} \quad (19)
\]

The effect of diffraction can be neglected when the width of the FOV contribution is much larger than the width of the diffraction contribution, that is, when

\[
\frac{\theta_{\text{max}}^2}{2} \gg \frac{1}{2} \left( \frac{3.83}{2 \pi r_o \sigma_o} \right)^2 \quad (20)
\]

Simplifying yields

\[
\theta_{\text{max}}^2 \sigma_o^2 \gg \frac{3.83^2}{2 \pi} = 0.37. \quad (21)
\]

Inequality (21) gives a condition that shows when the effect of diffraction can be neglected. It links the aperture size \( r_o \), the FOV size \( \theta_{\text{max}} \), and the wave number of the radiation \( \sigma_o \). Again, it is similar to the result derived from the accuracy consideration by Salonen et al.\(^8\) The condition obtained here stems, however, only from resolution considerations.

For example, if an instrument has an aperture with \( r_o = 1 \) cm and a half-divergence angle \( \theta_{\text{max}} = 1 \) mrad, both contributions have approximately the same width at \( \sigma_o = 610 \) cm\(^{-1}\). The condition to be able to neglect diffraction is therefore

\[
\sigma_o \gg 610 \text{ cm}^{-1}. \quad (22)
\]

In other words, in this case diffraction is negligible only for wavelengths appreciably smaller than 16.4 \( \mu \)m.

Another interesting reading of inequality (21) is possible by noting that the solid angle inside the interferometer is \( \Omega = 2\pi(1 - \cos \theta_{\text{max}}) \) and the area of the aperture is \( A = \pi r_o^2 \). This means that

\[
\Omega A \gg \frac{3.83^2}{4 \sigma_o^2}. \quad (23)
\]

However, \( \Omega A \) is simply the throughput \( \Theta \) of the instrument. The importance of diffraction in a FTS thus depends only on the throughput and the minimal wave number observed:

\[
\sigma_o^2 \gg \frac{3.83^2}{4 \Theta}. \quad (24)
\]

5. Comparing Beam Divergence, Interferogram Truncation, and Diffraction for Various Fourier-Transform Spectrometer Designs

The effect of diffraction on the line shape will now be compared qualitatively for various existing or currently planned FTSs. The compared instruments are listed in Table 1 along with the relevant parameters.

Figures 2–7 present the qualitative comparison for each instrument. On each graph the solid line of unit slope corresponds to \( \Delta(\sigma / \sigma_o)_{\text{distant}} = \Delta(\sigma / \sigma_o)_{\text{FOV}} \). This is the upper limit where diffraction is less important than the FOV effect.

The vertical continuous lines compare \( \Delta(\sigma / \sigma_o)_{\text{distant}} \) with \( \Delta(\sigma / \sigma_o)_{\text{FOV}} \) as given by relations (18) and (19), respectively. Since spectrally normalized line shapes are compared (spectral scale is \( \sigma / \sigma_o \)), the
The contribution of the FOV is constant, hence the vertical lines.

The diagonal dashed lines compare $\Delta(\sigma/\sigma_o)_{\text{diftact}}$ with $\Delta(\sigma/\sigma_o)_{\text{trunc}}$, where

$$\Delta(\sigma/\sigma_o)_{\text{trunc}} = \frac{1}{\text{MPD} \sigma_o},$$

with MPD being the maximal optical-path difference of the interferometer. Again, since normalized line shapes are compared, the width of the truncation contribution is a function of $\sigma_o$.

This approach allows a picture of the relative importance of each effect for a given interferometer to be plotted on a single graph.

The following paragraphs discuss the specifics of each instrument presented.

A. Spaceborne Instruments

1. Atmospheric Chemistry Experiment

The Atmospheric Chemistry Experiment (ACE), which will be flown by the Canadian Space Agency on the SCISAT-1 satellite, includes an interferometer with a spectral range of 750–4100 cm$^{-1}$. ACE is a solar occultation instrument that will measure compounds entering the ozone chemistry in the upper atmosphere. The instrument’s telescope has an aperture diameter of 100 mm, defines a FOV of 1.25 mrad, and has a magnification of 5. This means that, taking into account the metrology beam obscuration, the collimated beam in the interferometer has a radius of 1 cm and a half-angle of 3.125 mrad. The maximal optical-path difference is 25 cm.15,16

In Fig. 2 it can be seen that for ACE the truncation of the interferogram is the dominant effect for all the wavelengths. At the long wave edge, where diffraction is more important, the normalized widths for diffraction, FOV, and truncation contributions to the line shape are $3.3 \times 10^{-7}$, $4.9 \times 10^{-6}$, and $5.3 \times 10^{-5}$, respectively. This means that the effect of diffraction is 15 times narrower than the FOV effect and 160 times narrower than the cardinal sine. This is more than sufficient to affirm that diffraction will not have a major effect on ACE’s ILS.

One more observation is that, since the FOV contribution is always smaller than the cardinal sine, the instrument could have accepted a more divergent beam. This would allow for a higher throughput for the same pupil diameter. Some of the following instruments are more balanced in that respect. It is, however, important to understand that other parameters, such as the detector’s nonlinearity exacerbated by the high solar flux, have probably driven this choice for ACE.

2. Atmospheric Trace Molecule Spectroscopy Experiment

The Atmospheric Trace Molecule Spectroscopy (ATMOS) Experiment was flown for the first time on the space shuttle Challenger in April-May 1985 as part of the Spacelab 3 science payload.17–19 It was thereafter flown three more times on the Atmospheric Laboratory for Applications and Science space shuttle missions,20 the most recent being in November 1994. This solar occultation instrument covered a spectral range extending from 600 to 5000 cm$^{-1}$ at an unapodized resolution of 0.01 cm$^{-1}$. The 50-cm maximal optical-path difference needed to achieve this resolution was scanned symmetrically on each side of the zero path-difference point.

With a diameter of 7.5 cm the input telescope of the instrument defined a selectable FOV of 1, 2, or 4 mrad in the atmosphere. Since the magnification of the telescope was 2.6, the radius of the interferometer aperture was 1.44 cm, and the half-divergence angle was 1.3, 2.6, or 5.2 mrad.

The spectral widths produced on the ILS by interferogram truncation, finite FOV, and diffraction are compared for ATMOS in Fig. 3. Because ATMOS’s maximal path difference was twice that of ACE, the effect of the interferogram truncation was slightly shifted toward the diffraction limit. This shift was

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Spectral Range (cm$^{-1}$)</th>
<th>MPD (cm)</th>
<th>$\theta$ (mrad)</th>
<th>$r_o$ (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACE</td>
<td>750–4100</td>
<td>25</td>
<td>3.125</td>
<td>1</td>
</tr>
<tr>
<td>ATMOS</td>
<td>600–5000</td>
<td>50</td>
<td>1.3</td>
<td>1.44</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5.2</td>
<td></td>
</tr>
<tr>
<td>SOFIS</td>
<td>769–3077</td>
<td>2.5</td>
<td>0.85</td>
<td>0.6</td>
</tr>
<tr>
<td>FIRAS</td>
<td>1–96</td>
<td>5.85(1.22)</td>
<td>1000</td>
<td>0.39</td>
</tr>
<tr>
<td>MR254</td>
<td>510–14 000</td>
<td>1</td>
<td>1.79</td>
<td>1.27</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>22.86</td>
<td></td>
</tr>
<tr>
<td>DA8</td>
<td>4–50 000</td>
<td>250</td>
<td>0.81</td>
<td>3.81</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>16.13</td>
<td></td>
</tr>
</tbody>
</table>
nevertheless small enough that diffraction can be considered negligible.

Again, when the smallest FOV was selected, the dominant effect was clearly the truncation, so diffraction was never a problem. However, larger FOVs could be selected on ATMOS. As is obvious in Fig. 3, a larger FOV allowed the equalization of the truncation and finite FOV effects on the line shape. Because the two effects are combined on a monochromatic line by a convolution, having two equal widths means that the total line width will be roughly twice as large as when only one contribution is considered. Such a reduction of the resolution was indeed observed on the ATMOS spectra taken with the largest FOV. The ATMOS data could therefore benefit from an ILS removal algorithm.1,2,21,22


The Solar Occultation Fourier Transform Spectrometer for Inclined-Orbit Satellite (SOFIS) is another spaceborne FTS that will allow a better understanding of upper-atmosphere chemistry. It will be flown in 2006 by the National Institute for Environmental Studies and the National Space Development Agency of Japan.23–25

SOFIS has 0.2-cm⁻¹ resolution with a ±2.5-cm optical-path difference. Light collected from the sun will be sent into the interferometer by a 60-mm-diameter telescope having a magnification of 5. Its 0.34-mrad observing FOV in the atmosphere produces a beam in the interferometer with a radius of 0.6 cm and a half-diverging angle of 0.85 mrad. The spectral coverage extends from 3.25 to 13 μm, separated into two bands at 6.5 μm.

In Fig. 4 it is apparent that the diffraction contribution to the ILS is larger than that from the FOV for more than half of the long wavelength band. What is most striking, however, is that the importance of these two effects are orders of magnitude below the importance of the effect of interferogram truncation. The SOFIS line shapes should therefore be very close to the ideal cardinal sine in all circumstances. One other way to see it is that SOFIS is not making use of the throughput advantage because the beam divergence is kept small considering the moderate resolution of the instrument. Again, this was probably done because the high solar flux does not require a large throughput to achieve the required performance and too much light exacerbates detector nonlinearity problems.

4. Far Infrared Absolute Spectrophotometer

The Far Infrared Absolute Spectrophotometer (FIRAS) is on board the Cosmic Background Explorer. Its spectral range extends from 1 to 96 cm⁻¹ with a maximal optical-path difference of 5.85 (or 1.22) cm. The aperture area is 0.48 cm², and the solid angle sustained by the beam is π sr.26,27 The throughput is therefore 1.5 cm² sr.

From inequality (24) it is found that the diffraction and FOV contributions to the ILS are equal when σ₁ = 1.56 cm⁻¹. Diffraction should therefore have an appreciable contribution (more than 1%) for all wave numbers smaller than 15 cm⁻¹.

Figure 5 shows that, for the longest optical-path difference, diffraction dominates below 1.56 cm⁻¹, and the FOV contribution should dominate at longer wavelengths. This distinction between FOV and diffraction is, however, a bit misleading. The diffraction has obviously been managed in FIRAS. As stated in Ref. 26 and 27, “The sky horn has a smoothly flared aperture to reduce diffractive side-lobes over a wide frequency range.”

The full beam divergence in the interferometer is 2 rads. Of course, with such a wide FOV one will observe nonuniformities in the angular distribution of the light in the interferometer. The FOV contribution to the ILS will therefore not be a boxcar. This is
a case where the radiation pattern of the light-gathering optics should be obtained either from modeling or from measurements and then used as input for the line-shape model. The FOV and diffraction contributions would then be taken into account properly, that is, simultaneously.

B. Commercial Instruments

To complete this overview of specific FTSs, two commercial instruments are added to the qualitative comparison. These are the MR254 and the DA8 from ABB Bomem.

1. ABB Bomem MR254

The MR254 is a low-resolution instrument (±1-cm MPD) that covers the range from 510 to 14 000 cm\(^{-1}\). It has seven possible discrete field stops (from 0.5 to 6.4 mm) in the focal plane of a 14-cm collimator, which allows for a diverging beam with a half-angle from 1.79 to 22.86 mrad. The collimated beam has a radius of 1.27 cm. With these numbers, however, one obtains a throughput slightly higher than that specified (0.0045 cm\(^2\) sr) in the commercial brochure,\(^{28}\) which probably takes into account the obscuration caused by the metrology beam.

Figure 6 shows that for the maximal FOV diameter the effect of interferogram truncation and beam divergence are fairly well balanced and that they are both far away from the diffraction limit, by factors of 4545 and 590, respectively. The smaller field stop brings the FOV effect near the diffraction limit factor of 3, but this is irrelevant since in that case truncation dominates by a large amount.

2. ABB Bomem DA8

The DA8, on the other hand, is ABB Bomem’s high-resolution instrument.\(^{29}\) It has a maximal optical-path difference of 250 cm with a spectral coverage that extends from 4 to 50 000 cm\(^{-1}\) with different beam splitter sets. The clear aperture in the collimated space is 40 cm\(^2\). Given the central obscuration for the metrology beam, this yields a 3.81-cm pupil radius. The field stop is in the focal plane of a 31-cm collimator. It has a variable diameter with eight discrete steps from 0.5 to 10 mm. This produces a diverging-beam half-angle between 0.81 and 16.13 mrad.

In Fig. 7 it is seen that the FOV can be opened enough to balance the effect of the interferogram truncation. The other noticeable point is that in the far infrared the truncation effect approaches the diffraction limit. The DA8 line shapes in that spectral region therefore exhibit some distortion due to diffraction.
6. Conclusion

This paper has presented a simple analysis of diffraction on the ILS of FTSs. Results comparable with those presented by Salonen et al. were obtained more formally, taking radiometry into account. A simple condition stating the importance of the diffraction with respect to the FOV effect was given. Qualitative comparison of the contribution of diffraction, interferogram truncation, and FOV to the line shape showed that under normal conditions diffraction is important only for instruments measuring in the far infrared, as was expected.

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