SPECTROSCOPY WITH FORS

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Abstract. The FORS instrument is a focal reducer which is under construction for the Cassegrain focus of the ESO VLT telescopes. FORS is being built by a consortium of three german institutes. It is optimized for spectroscopy and imaging of very faint sources.

1. Introduction

The FORS (FOcal Reducer Spectrograph) instrument for ESO's Very Large Telescope (VLT) is a focal reducer-type instrument which is presently being built by the Landessternwarte Heidelberg, the Uni-Sternwarte München and the Uni-Sternwarte Göttingen. For a description of the instrument see e.g. Appenzeller and Rupprecht (1992), Seifert et al. (1994) and Böhnhardt et al. (1995). In the following, only a brief description of the instrument is given.

The FORS optics is optimized for good image quality and good transmission over an extended wavelength range (330 nm to 1100 nm).

This makes it especially suited for deep imaging and spectroscopy of the faintest sources.

Two copies will be installed at the VLT telescopes UT1 (FORS1) and UT3 (FORS2).

TABLE 1. FORS Observing modes

Observing mode	Hardware
Direct Imaging	2 collimators 7 broadband filter positions 8 interference filter positions
Spectroscopy	multi slit unit (19 slitlets) 9 longslits 7 grism positions
Polarimetry (FORS1 only)	2 phase retarder plates (linear/circular polarimetry) 1 Wollaston prism 1 mask or multi slit unit (for strip mask)
Spectropolarimetry (FORS1 only)	combination of equipment for spectroscopy and polarimetry
Medium dispersion echelle spectroscopy) (FORS2 only)	additional grisms for cross-dispersion
Optional	6 positions (FORS1) or 7 positions (FORS2) for additional optical components (filters, grisms)

1.1. FORS OBSERVING MODES

FORS is designed as a flexible multi-purpose instrument. A large selection of filters and grisms will be available: three wheels in the parallel beam provide 21 positions available for filters, grisms and polarization optics.

1.2. BASIC INSTRUMENT LAYOUT

A special feature of FORS is the quickly reconfigurable MOS unit. This mechanically complex unit consists of 2×19 individually moveable slitlets, each 12 mm ($22''.5$) wide. The curvature of the field of view (parallel to dispersion) is taken into account.

Two collimators, which can be exchanged easily (and quickly) under remote control, provide two different image scales and field sizes.

In standard resolution (SR) and high resolution (HR) mode the image scales are $0\farcs2$/pixel and $0\farcs1$/pixel, respectively, providing a field of view of $6\farcm8 \times 6\farcm8$ and $3\farcm4 \times 3\farcm4$, respectively.

80% of the encircled energy falls within one pixel within the central $4'$and $2'$, respectively.

The parallel beam section contains filters, grisms and polarization optics.

The camera field lens compensates for the curvature of the detector. It can be exchanged, if a flat detector should become available later.

The detector is a 2048×2048 pixel CCD with 24μm pixels, thinned and anti-reflection coated. The complete detector system consisting of CCD, vacuum system and controller, will be provided by ESO.

1.3. THE MOS UNIT

The MOS unit has been described in detail by Mitsch et al. (1994). It was designed with the following main requirements:

It should provide as many slits as possible, with high spectrophotometric accuracy, and fast and reliable operation. It should be possible to change quickly to imaging mode and it should be completely under remote control.

The final solution consists of 19 slitlets with $22\farcs5$ length, all individually controlled, which allows fast reconfiguration.

The number of slitlets appears quite limited, but is determined by the field of view and the length of the individual slitlets. The latter is determined by the mechanical properties of the slitlets and drives and the requirement of enough sky background for precise sky subtraction.

Although 19 slitlets is a of course a small number compared to existing systems using optical fibers, it should be kept in mind that FORS is designed for the faintest objects, where slitlets have advantages compared to fiber systems.

For long-slit spectroscopy 9 slits with different (fixed) slit-widths from $0\farcs5$ to $1\farcs5$ are provided.

1.4. AVAILABLE GRISMS

The set of grisms foreseen for FORS has been described by Fürtig and Seifert (1995). The available dispersions will range from about 45 to 230 Åmm^{-1} for the standard grisms and about 15 to 41 Åmm^{-1} for the high-dispersion echelle mode foreseen for FORS2.

TABLE 2. FORS standard grisms. The listed resolutions are for a 1″ slit.

Grism	Wavelength range [nm]	Dispersion [Å/mm]	Resolution	Order sorting filters
1	350 - 590	50	815	none
2	525 - 740	45	1230	GG435
3	690 - 910	44	1530	OG590
4	800 - 1030	45	1760	OG590
5	330 - 860	111	420 (500)	(GG435)
6	600 - 1140	108	680	OG590
7	330 - 1100	228	185 (280)	(OG590)

TABLE 3. Limiting magnitudes calculated for a signal-to-noise ratio of 10 and a seeing and slit width of 1″.

Wavelength	dispersion	Integration Time		
(Å)	(Å/mm)	60 s	600 s	1800 s
3600	150	18.3	20.7	21.9
	50	17.2	19.7	20.9
4400	150	19.8	22.3	23.4
	50	18.8	21.3	22.4
5500	150	19.7	22.1	23.2
	50	18.6	21.1	22.3
6500	150	19.4	21.8	22.8
	50	18.3	20.8	21.9

1.5. FORS POLARIMETRY MODES

In the foreseeable future, FORS will be the only optical instrument with polarimetric capabilities at the VLT. Probably very few 8 m class telescopes with such instruments will be available.

Due to the large diameter of the collimated beam (90 mm), the polarimetric optics is very large. Superachromatic retarder plates of the required size cannot be made, therefore mosaics have to be used. This will limit the possible accuracy in polarimetric mode.

For imaging polarimetry and spectropolarimetry (linear and circular) a Wollaston prism and two 3×3 mosaics of retarder plates ($\lambda/4$ and $\lambda/2$) will be available at FORS1.

The limiting magnitudes for circular polarization will be at least as

TABLE 4. Predicted performance of FORS in polarimetric and spectropolarimetric mode (linear polarization). Parameters: 1 h exposure time, seeing and slit width of 1″, dispersion of 50 Åmm^{-1}, 1 % accuracy in the degree of linear polarization.

Filter	polarimetry	spectropolarimetry
U	22.1	15.9
B	23.3	17.4
V	22.6	17.3
R	22.1	17.0

deep with the same total exposure time, since only one Stokes parameter is obtained.

1.6. FORS SOFTWARE

The Instrument Related Software (IRS) will control all functions of the instrument (from Paranal or Garching), including change of filters, grisms, slitlets and also the collimator exchange.

All images obtained with FORS will be sent to the ESO archive. In addition, the images will be sent to "on-line Midas", where an automatic quick look data reduction is performed (for all observing modes).

The "quick-look" data reduction sotware (DRS) is a stripped down version of the "off-line" DRS, which will be supplied with the instrument.

This "off-line DRS" is designed as general purpose data reduction software. For FORS data it requires little user interaction, but it can be adapted to other data as well.

2. FORS status

FORS1 will be one of the first instruments at the VLT (1998). It is already in an advanced state.

- Optics: Most parts are finished and have already been tested in the lab, except grisms and filters
- Mechanics: Most parts of FORS1 are finished, FORS2 has been started
- Electronics: In progress
- Instrument related software: In progress
- Data reduction software: In progress
- CCD: in ESO lab

Assembly of the whole instrument and tests at the Telescope and Star Simulator will start in the fall of 1996. For a detailed description about the tests and calibrations see Möhler et al. (1996). The tests will include:

– mechanics, electronics, software
– image quality over the whole field
– optical distortion
– instrument transmission
– image motion due to flexure (specified as < 0.25 (pixel/2 hours))

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