

# Optimisation of Instruments

Arnoud Apituley  
Volker Freudenthaler  
Adolfo Comeron

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WMO, Geneva



# Outline

- Goals
- Methodology and Tools
- Progress and Status
- Conclusions



# Goals

- Improving the EARLINET installed base of lidars
  1. Performance
  2. Homogeneity
  3. Operationality
- Selecting optimum technical solutions for instrumental problems
- Recommendations for implementation across the network
- Facilitate expansion of the network



# Performance

- Which parameters should be optimised?

**Table 1: Measurement characteristics as required for the main application areas. Backscatter lidar (BL), Raman lidar (RL), depolarization lidar (DL), and high spectral resolution lidar (HSRL). These methods can be applied either at one or at multiple wavelengths (MBL, MRL).  $\alpha$  = extinction,  $\beta$  = backscatter,  $\delta$  = depolarization,  $S_a$  = lidar ratio, MPP = microphysical properties.**

Application area	Parameters required	Instrument type	Operation required	Number of stations
1.a Global climatology	$\alpha, \delta, (\beta, S_a)$	RL	fixed schedule, 3/week	20?
1.b Model evaluation	$\alpha, \delta, (\beta, S_a, MPP)$	MRL	fixed schedule + diurnal cycles	
1.c Transport and tracers	$\beta, (\alpha, \delta, MPP)$	BL	fixed schedule + on alert	50
1.d Radiation	$\alpha, \beta, (\delta)$	RL	random	20
2.a Air quality assessment	$\alpha, \delta, \beta, MPP$	RL	fixed schedule	50+
2.b Air quality forecast	B	BL	quasi-continuous	??
3. Plumes from special events	$\beta, (\alpha, \delta, MPP)$	BL	on alert	50
4.a Ground truth	$\alpha, \delta, \beta, S_a$	MRL	TBD	20
4.b Complementary information	$\alpha, \delta, \beta, S_a$	MRL	fixed schedule	20

GAW report 178, WMO/TD-No. 1443



# Performance

- Which lidar configurations?

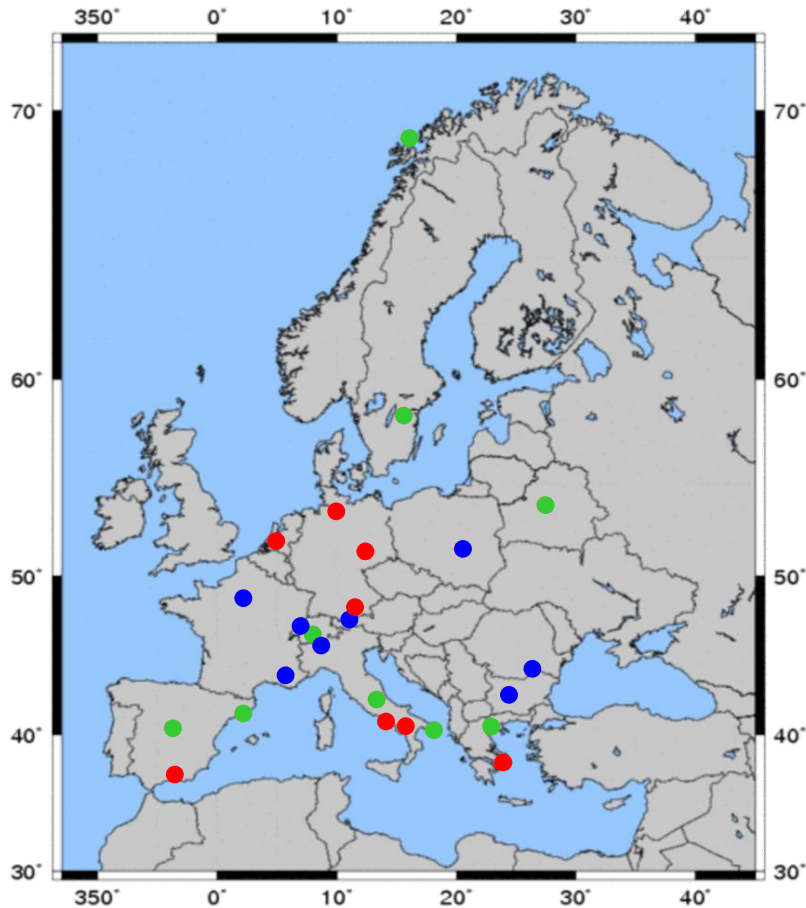
**Table 3: Aerosol properties that can be derived from lidar observations. Only the simplest lidar type that is needed to provide the product is listed. Depolarization channels (DL) are required to identify desert dust.**

Parameter (product)	Basic lidar type
Range corrected signal (colour plots of aerosol and cloud distributions)	BL
Attenuated backscatter coefficient (calibrated range-corrected signal)	BL
PBL depth	BL
Aerosol backscatter coefficient	BL+SPM
Aerosol type discrimination (dust, anthropogenic)	BL+DL
Aerosol extinction coefficient (estimate), optical depth, column lidar ratio	BL+SPM
Aerosol extinction coefficient, optical depth, lidar ratio	RL or HSRL
Ångström exponent (backscatter-related)	MBL
Ångström exponent (extinction-related)	MRL
Aerosol type determination (dust, maritime, fire smoke, urban haze)	MRL+DL
Aerosol microphysical properties (volume and surface conc., refractive index)	MRL
Single scattering albedo (aerosol)	MRL

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# Homogeneity?



- Multi-wavelength Raman (3+2)
- Raman
- Backscatter

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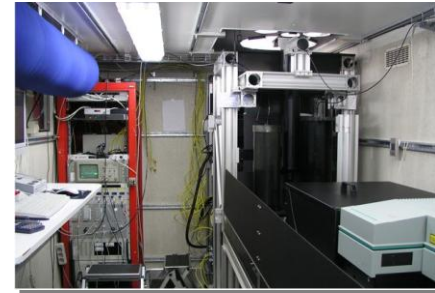




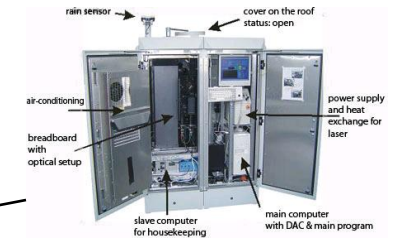
Bilthoven/Cabauw, NL



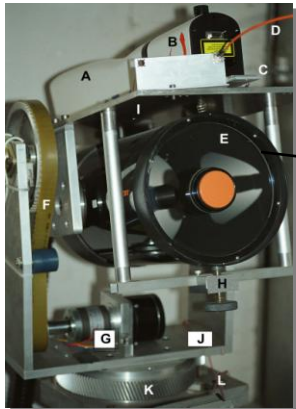
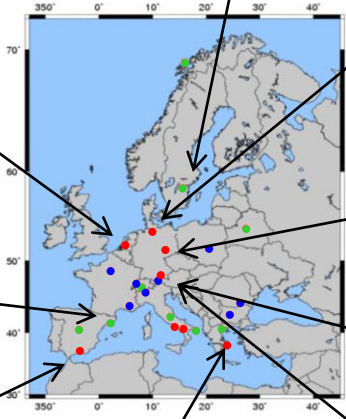
Linköping, SE



Hamburg, DE



Leipzig/Melpitz, DE



Barcelona, ES



Athens, GR



Garmisch-Partenkirchen, DE



München, DE

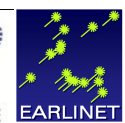


Granada, ES

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# Operationality

- Increase level of automation
  - e.g. measurement start-up procedures
  - Full autonomous operation
- Decrease need for operator controlled measurements
  - e.g. safety and control





# Expected Results

- Enhanced homogeneity of performance over the network
  - Quantitative data products
- Better coverage of vertical range
  - Including the boundary layer
- Increased temporal coverage
  - Improved Raman daytime performance
  - Increased level of automation (capture events)
- Facilitate expansion of the network
- Possible: spin-off to SME for production of standardised components
- 



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- Possible: spin-off to SME for production of standardised components
- **Expansion of deliverable data products**
  - Cloud products, ash, faster data delivery



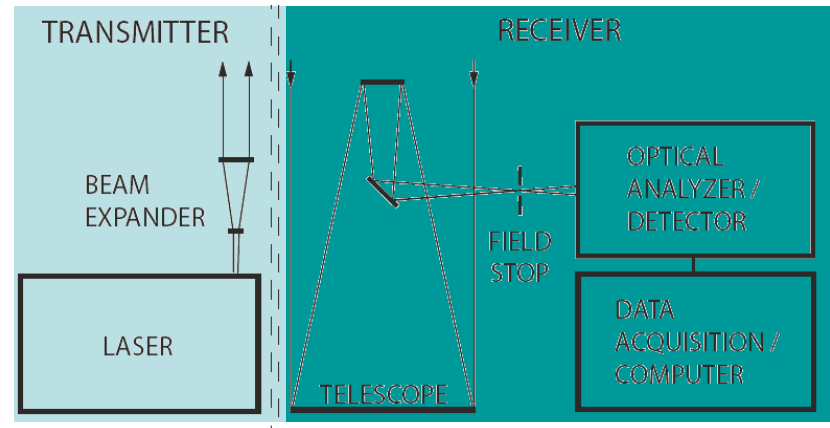
# Methodology and Tools

- Handbook of Instruments
  - Extensive set of system parameters
  - Exploitation of handbook data
- Repository of techniques
  - Solutions for technical problems
- Analysis tools
  - Optical configuration (ray-tracing)
  - Electronics recommendations and testing procedures



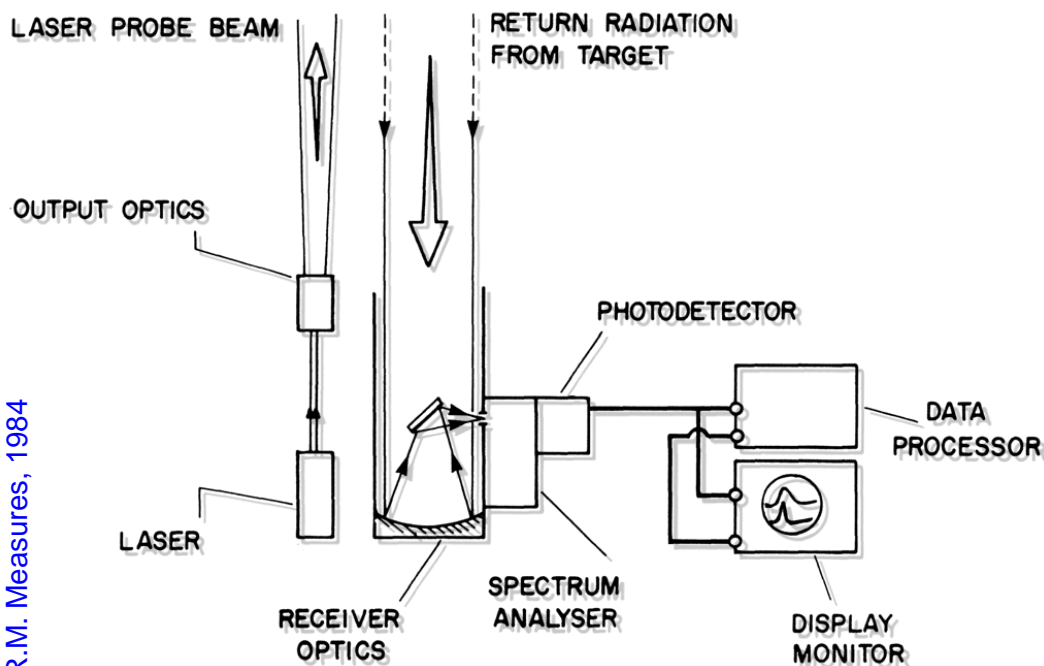
# Handbook of Instruments

- Detailed description of each individual station
- Generic format to allow wide variety of designs
- Blocks of information
  - Station information (location, name, etc.)
  - Emitter description (wavelengths, control systems)
  - Optical receiver
  - Wavelength separation
  - Detectors
  - Data acquisition
  - Ancillary station information (nearest sonde, sunphotometer)



# Handbook Example

- 1-lambda Backscatter lidar



R.M. Measures, 1984

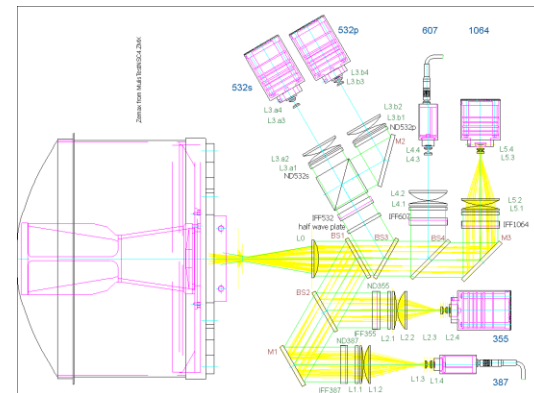
Parameter	Value	Unit
Manufacturer	10710248	
Name	10710248	
Model	10710248	
Year	10710248	
Serial number	10710248	
Weight	10710248	kg
Dimensions	10710248	m
Power	10710248	W
Wavelength	10710248	nm
Beam diameter	10710248	cm
Beam divergence	10710248	deg
Repetition rate	10710248	Hz
Range resolution	10710248	m
Range accuracy	10710248	m
Range precision	10710248	m
Range stability	10710248	m
Range repeatability	10710248	m
Range drift	10710248	m
Range hysteresis	10710248	m
Range lag	10710248	m
Range lag error	10710248	m
Range lag drift	10710248	m
Range lag hysteresis	10710248	m
Range lag repeatability	10710248	m
Range lag drift	10710248	m
Range lag hysteresis	10710248	m
Range lag repeatability	10710248	m
Range lag drift	10710248	m
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Range lag drift	10710248	m
Range lag hysteresis	10710248	m
Range lag repeatability	10710248	m
Range lag drift	10710248	m
Range lag hysteresis	10710248	m
Range lag repeatability	10710248	m



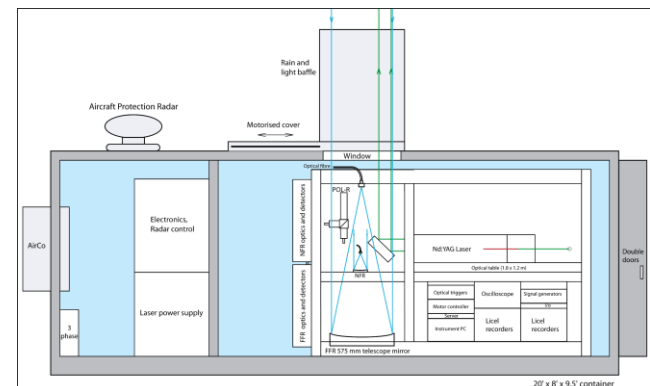
# Handbook Example

## • Multi-wavelength Raman Lidar

GALILEO System		SW 5000	
<b>System name</b>			
System name: GALILEO			
System location: Galileo			
System location: Galileo			
System location: Galileo			
<b>System description</b>			
System description: GALILEO			
<b>System components</b>			
System components: GALILEO			
<b>System specifications</b>			
System specifications: GALILEO			
<b>System performance</b>			
System performance: GALILEO			
<b>System maintenance</b>			
System maintenance: GALILEO			
<b>System safety</b>			
System safety: GALILEO			
<b>System documentation</b>			
System documentation: GALILEO			



MULIS, V. Freudenthaler



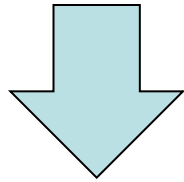
CAELI, A. Apituley





# Handbook Updating

- Spreadsheet
  - Tedious updating process
  - Difficult to couple to profiles in database



- Database with admin-access via web
  - Easier to maintain
  - System configuration traceable to specific date
  - Automatic access (data processing purposes)
  - Public interface for general overview

# Handbook Updating

**Earlinet adminpages**

SF  
BH  
AN

Station Emitter Receiver

#call-sign BH  
 #lidar\_system\_name  
 #updated 2010-03-25 14:07  
 #description Bilthoven - Rijksinst  
 #name Caeli  
 #location Bilthoven, NL  
 #lat 52.12  
 #lon 5.2  
 #alt 5  
 #environment urban  
 #transportable no

	call-sign	_updated	_receiver	#wavelength	scattering_mechanism	wavelength_separation	separation_passband	bandwidth	separation_transmis
<input type="checkbox"/>	SF	2010-03-29 10:59:21	Telescope 1	510.6 nm	Elastic				
<input type="checkbox"/>	SF	2010-03-29 10:59:21	Telescope 3	1064 nm	Elastic	DBS			
<input type="checkbox"/>	SF	2010-03-29 10:59:21	Telescope 3	532 nm	Elastic	DBS			
<input type="checkbox"/>	SF	2010-03-29 10:59:21	Telescope 3	607 nm (devel)	Vibr.Raman N2	DBS			
<input type="checkbox"/>	BH	2010-03-25 14:07:33	Telescope 1	1064 nm	Elastic	DBS			
<input type="checkbox"/>	BH	2010-03-25 14:07:33	Telescope 1	387 nm	vibr.Raman N2	DBS			
<input type="checkbox"/>	BH	2010-03-25 14:07:33	Telescope 1	355 nm	Elastic	DBS			
<input type="checkbox"/>	BH	2010-03-25 14:07:33	Telescope 1	607 nm	vibr.Raman N2	DBS			
<input type="checkbox"/>	BH	2010-03-25 14:07:33	Telescope 1	407 nm	vibr.Raman WV	DBS			
<input type="checkbox"/>	BH	2010-03-25 14:07:33	Telescope 1	532 nm	Elastic	DBS			
<input type="checkbox"/>	BH	2010-03-25 14:07:33	Telescope 2	532 nm	Elastic parallel	n.a.			
<input type="checkbox"/>	AN	2007-01-15 00:00:00	Telescope 1	355	Elastic	DBS		0.2	
<input type="checkbox"/>	AN	2007-01-15 00:00:00	Telescope 1	387	Vibr.Raman N2	DBS		0.2	
<input type="checkbox"/>	AN	2007-01-15 00:00:00	Telescope 1	408	Vibr.Raman H2O	DBS		0.2	
<input type="checkbox"/>	AN	2007-01-15 00:00:00	Telescope 1	532	Elastic parallel	DBS		0.35	
<input type="checkbox"/>	AN	2007-01-15 00:00:00	Telescope 1	608	Vibr.Raman N2	DBS		0.2	
<input type="checkbox"/>	AN	2007-01-15 00:00:00	Telescope 1	660	Vibr.Raman H2O	DBS		10	
<input type="checkbox"/>	AN	2007-01-15 00:00:00	Telescope 1	1064	Elastic	DBS		0.2	

<http://cerberus.rivm.nl/earlinet/earlinet.php>

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# Handbook Public View

EARLINET - Handbook of instruments

Earlinet Stations

SF  
BH  
AN

Map Satellite Hybrid

POWERED BY Google 2000 mi 2000 km

Imagery ©2010 TerraMetrics, NASA - Terms of Use

[http://cerberus.rivm.nl/earlinet/index\\_new.php](http://cerberus.rivm.nl/earlinet/index_new.php)

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SIXTH FRAMEWORK PROGRAMME



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# Handbook Public View

The screenshot shows a web browser window with the URL [http://cerberus.rivm.nl/earlinet/index\\_new.php](http://cerberus.rivm.nl/earlinet/index_new.php). The page title is "EARLINET - Handbook of instruments". The main content area displays a map of Europe with a callout box for a station. The callout box has tabs for "Station", "Photo", "Emitter", and "Receiver". The "Station" tab is active, showing the following details:

call-sign	BH
lidar_system_name	
updated	2010-03-25 14:07:33
description	Bilthoven - Rijksinstituut voor Volksgezondheid en Milieu (RIVM)
name	Caeli
location	Bilthoven, NL
lat	52.12
lon	5.2
alt	5
environment	urban
transportable	no

The map shows the location of the station in the Netherlands. The page also includes a sidebar with "Earlinet Stations" and a list of stations: SF, BH, AN. The bottom of the map area includes a scale bar (200 mi, 500 km) and the text "Imagery ©2010 TerraMetrics - Terms of Use".

[http://cerberus.rivm.nl/earlinet/index\\_new.php](http://cerberus.rivm.nl/earlinet/index_new.php)

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# Handbook Public View

The screenshot shows a web browser window with the URL [http://cerberus.rivm.nl/earlinet/index\\_new.php](http://cerberus.rivm.nl/earlinet/index_new.php). The page title is "EARLINET - Handbook of instruments". The navigation menu includes: rivm, knmi, Lidar, EARLINET, Projects, Climate, EarthObs, Journals, Events, Org, Sites, Groups, Persons, Vendors, Privé, Info, tmp, Apple (145). The main content area features a map of Europe with a callout box. The callout box has tabs for "Station", "Photo", "Emitter", and "Receiver". It contains two images: a night-time photo of a lidar system in operation with a green laser beam visible, and a photo of the lidar equipment in a laboratory setting. Below the images is the text: "Pictures of the lidar in operation and in the lab." The map includes a scale bar (200 mi, 500 km) and a copyright notice: "Imagery ©2010 TerraMetrics - Terms of Use".

[http://cerberus.rivm.nl/earlinet/index\\_new.php](http://cerberus.rivm.nl/earlinet/index_new.php)

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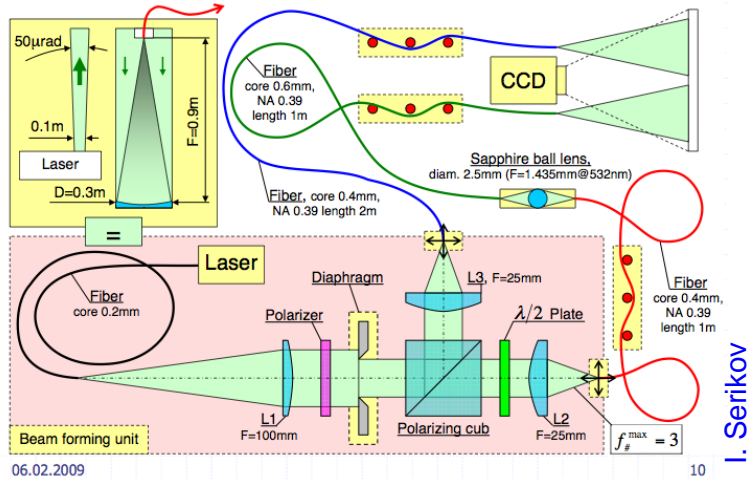




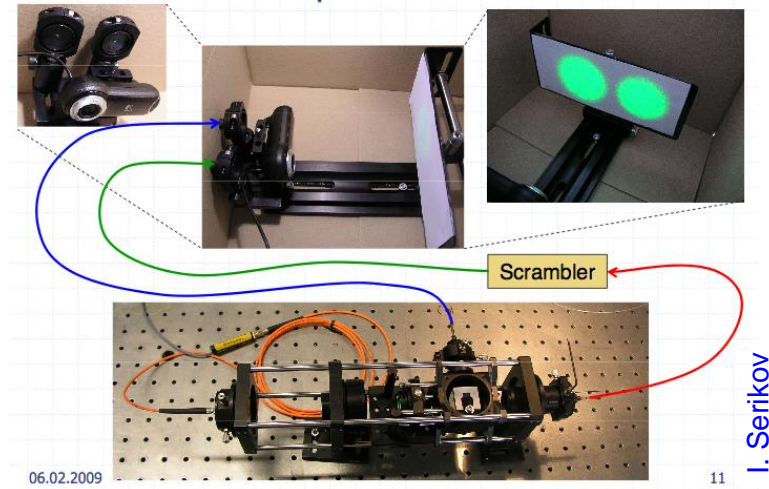
# Repository of Techniques and Solutions

- Techniques are presented and discussed during workshops
- Documentation materials made accessible

Scrambler: experimental verification

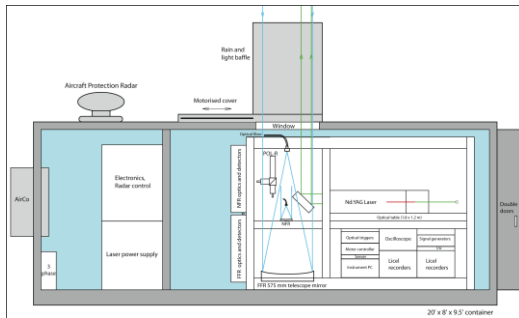
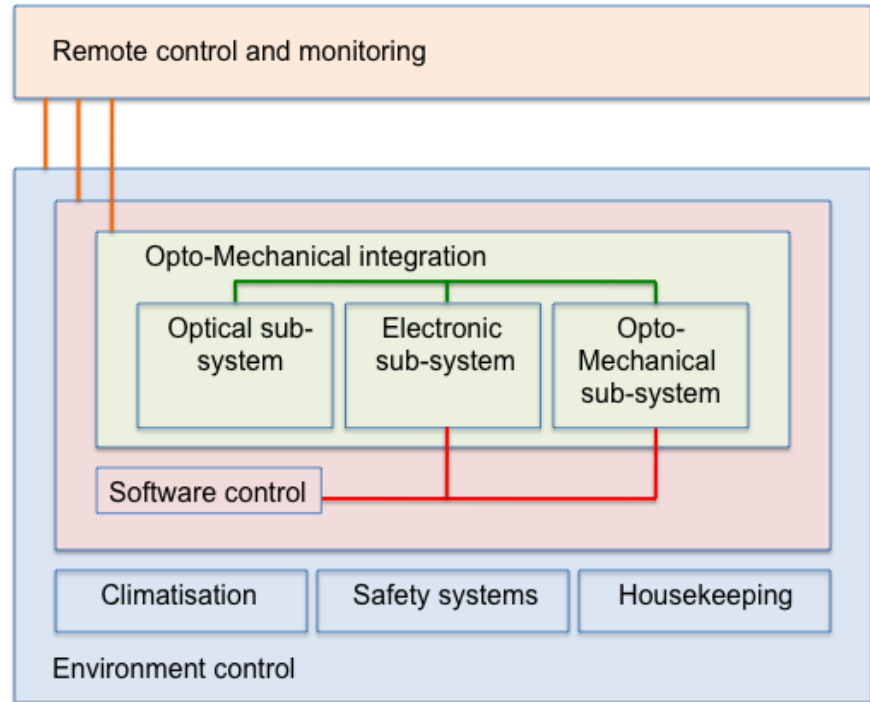


The scrambler: experimental verification



# System Integration and Automation

- Recommendations to put sub systems together
  - Serviceable (modular, replaceable, upgradable)
  - Instrument control software integration
  - Electrical connections to avoid problems
  - Computer Interfacing
  - Remote control



# Commercial Systems

- Commercially available systems are available
  - In use in Granada, Leipzig, Evora, Bucharest, Ispra, Palaiseau
  - Instruments have to pass through network QA/QC procedures before data can be accepted in the database
- Common parts
  - Interact with suppliers for common specifications and custom configurations



# Progress and Status

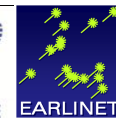
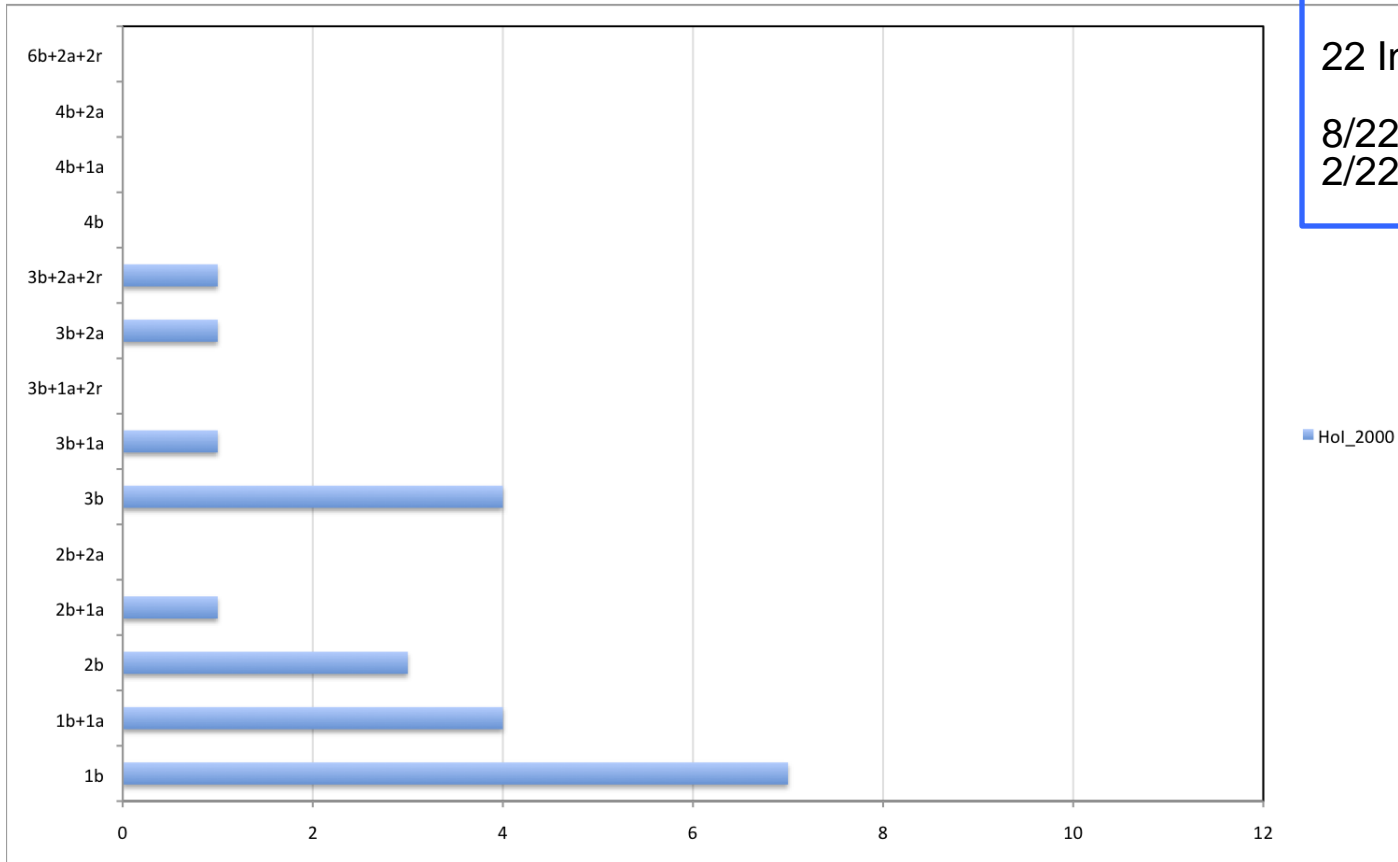
- Instrument installed base development since 2000

Station	Country	System name	Lat	Lon	2000	2006	2010
Abastumani	GE		41.75 N	42.82 E	-	-	-
Aberystwyth	GB		52.4 N	4.06 W	1b+1a	-	-
Andenes	NO	ALOMAR Troposphere Lidar	69.278 N	16.008 E	-	3b+2a	3b+2a
Athens	GR	EOLE	37.9716 N	23.7875 E	1b	3b+2a	3b+2a
Barcelona	ES	UPCLidar	41.393 N	2.120 E	1b	2b	2b+1a
Belsk	PO		51.5 N	20.47 E	3b	2b	3b
Bucharest	RO	LISA	44.348 N	26.029 E	-	2b	-
		RALI			-	-	3b+2a
Cabauw	NL	RBL	51.97 N	4.93 E	-	1b	-
		Caeli			-	-	3b+2a
Cork	IR				-	-	-
Evora	PT		38.568 N	7.912 W	-	-	3b+2a
Garmisch-Partenkirchen	DE		47.476 N	11.063 E	3b	-	-
		NDSC lidar			-	2b	2b
		HSRL			-	2b+1a	2b+1a
Granada	ES	Raymetrics LR321 - D400	37.164 N	3.605 W	-	3b+1a	3b+2a
Hamburg	DE	ARL2	53.568 N	9.973 E	1b+1a	3b	3b+1a+2r
Ispra	IT	CIMEL	45.811 N	8.621 E	-	1b	1b
Kühlungsborn	DE		54.1167 N	11.7667 E	3b+2a	-	-
L'Acquila	IT		42.344 N	13.327 E	1b+1a	1b+1a	1b+1a
Lausanne	CH	EPFL-MeteoSwiss	46.5481 N	7.9839 E	3b+1a	2b+2a	-
Lecce	IT	UniLe	40.33 N	18.10 E	1b+1a	1b+1a	1b+1a
Leipzig	DE	Martha	51.35 N	12.43 E	3b+2a+2r	3b+2a+2r	3b+2a+2r
		Bertha			-	6b+2a+2r	6b+2a+2r
		Polly			-	1b+1a	1b+1a
		Polly-XT			-	-	3b+2a
Linköping	SE	FOI UV Lidar	58.392 N	15.575 E	1b	2b+2a	2b+2a
Lisbon	PT		37 N	8.5 W	1b	-	-
Ljubljana	SI		46.0 N	14.5 E	1b	-	-
Madrid	ES	LIDAR-CIEMAT	40.456 N	3.726 W	-	1b+1a	1b+1a
Maisach	DE	POLIS	48.209 N	11.258 E	-	1b+1a	1b+1a
Minsk	BY	MSTL-2	53.917 N	27.383 E	2b	4b+1a	4b+2a
München	DE	MULIS	48.15 N	11.57 E	3b	3b+2a	3b+2a
Napoli	IT		40.833 N	14.183 E	1b	3b+2a	2b+2a
Ness-Ziona	IL	IIBR	31.55 N	34.47 E	-	-	2b
Neuchatel	CH	MAL-ground	47.001 N	6.955 E	3b	1b	1b
Oxyliothos	GR	EOLE-OXY	38.55 N	24.13 E	-	-	-
Palaiseau	FR	LNA	48.42 N	2.16 E	2b	2b	-
		ALS450			-	-	1b
Payerne	CH	RALMO	46.812 N	6.943 E	-	-	1b+1a
Potenza	IT	PEARL	40.6 N	15.733 E	2b+1a	3b+2a	3b+2a
		MUSA			-	-	3b+2a
Saint-Michel (HP)	FR	LTA-LOR	43.935 N	5.712 E	-	1b+1a	1b+1a
Sofia	BU	Sofia-EARLINET station IE	42.65 N	24.38 E	2b	3b+1a	3b+1a
Thessaloniki	GR	AUTH	40.5N	22.9 E	1b	3b	2b+2a



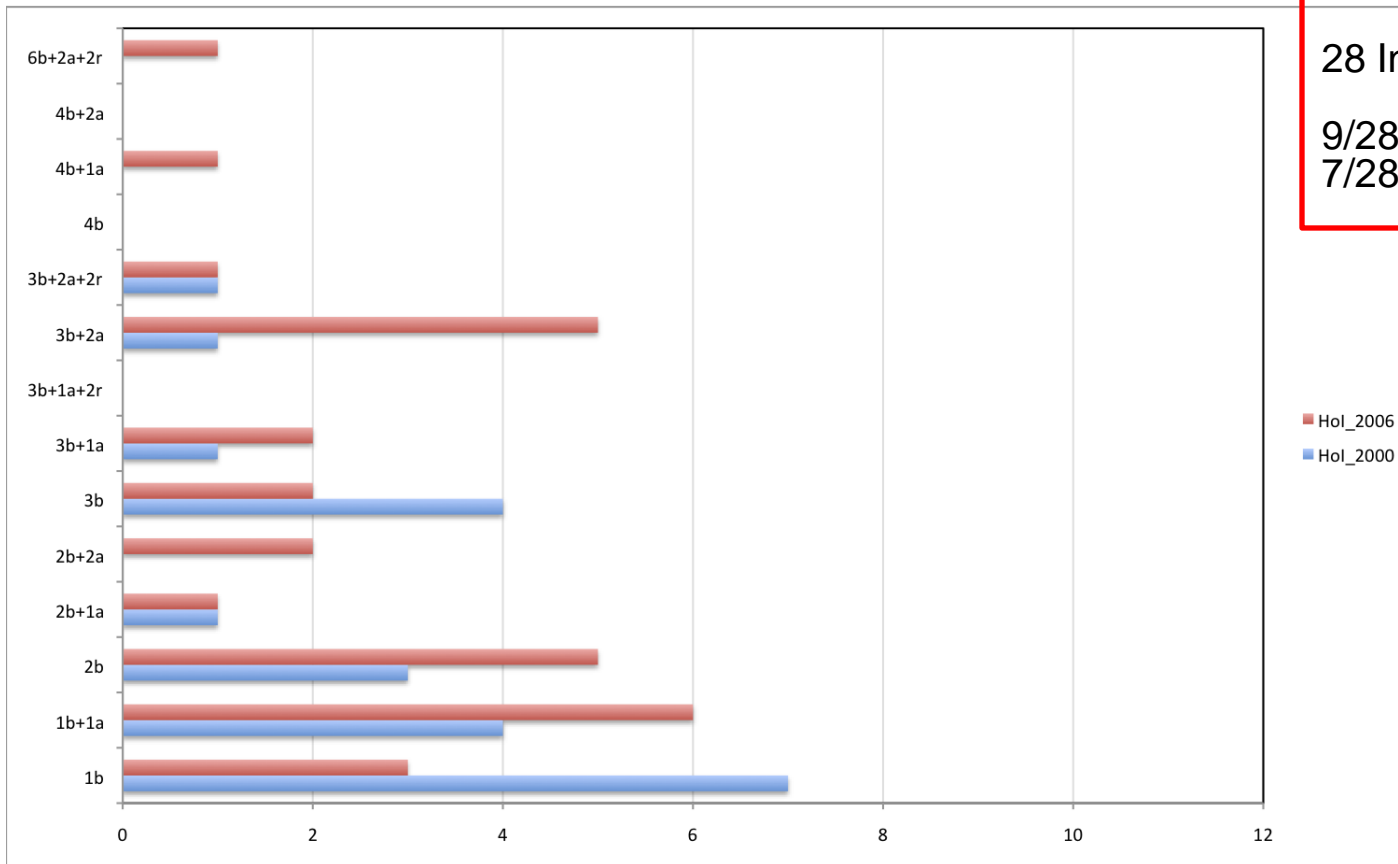
# Network Development

**2000**  
 22 Instruments  
 8/22 Raman capable  
 2/22 High performance



# Network Development

**2006**  
 28 Instruments  
 9/28 Raman capable  
 7/28 High performance



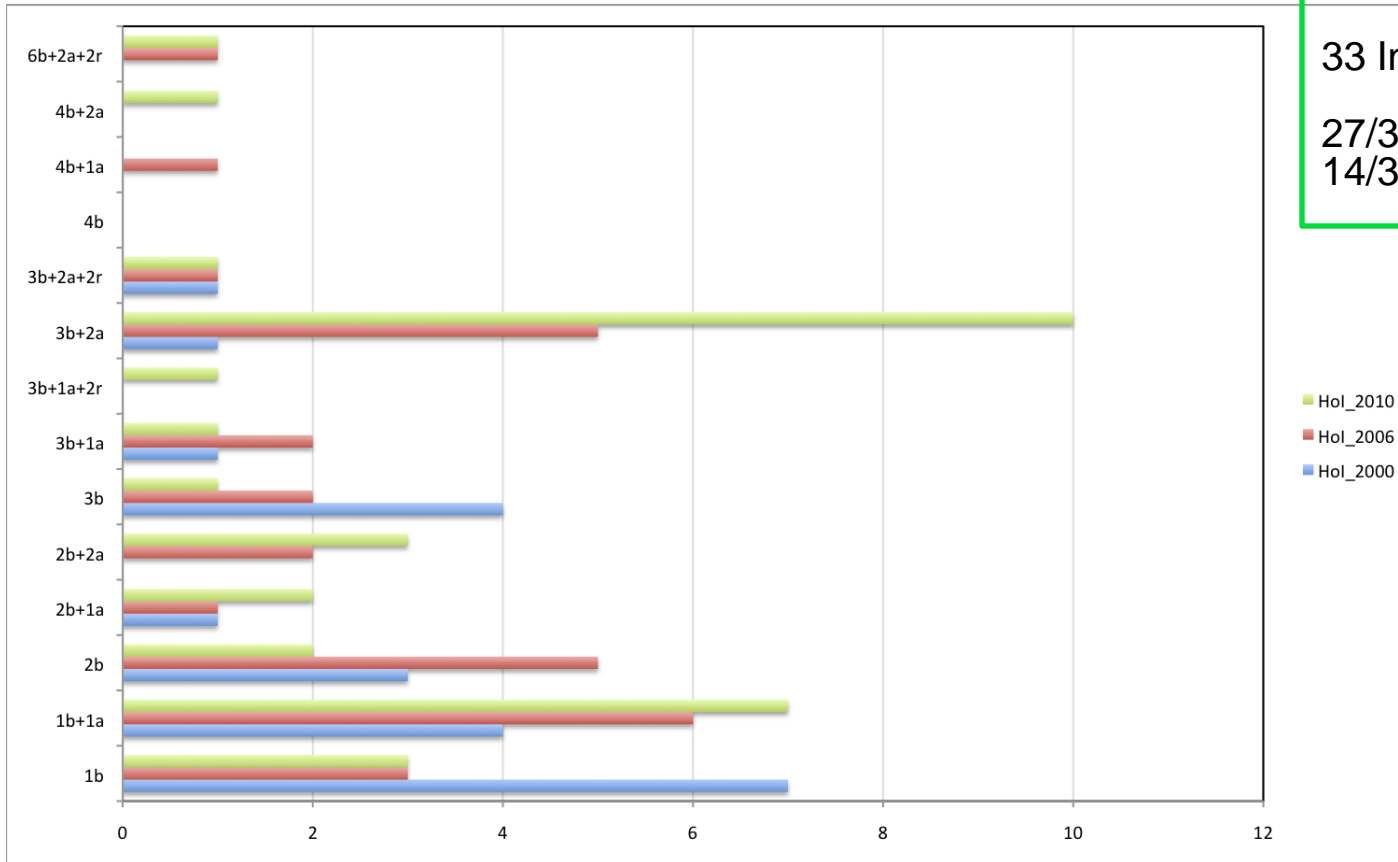


# Network Development

**2010**

33 Instruments

27/33 Raman capable  
14/33 High performance



■ HoI\_2010  
■ HoI\_2006  
■ HoI\_2000

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# Conclusions

- Tools exist for keeping track of the development and quality of the installed base of instruments in the network
- Recommendations and techniques for network participants and aspiring partners available
- Improvement of tools and repository of recommendations is ongoing
- Commercial systems are becoming part of the network
- Network has expanded and performance in terms of network objectives has increased

