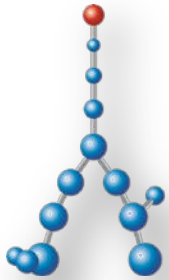


DSTF
Dipartimento di Scienza
e Tecnologia del Farmaco
UNIVERSITÀ DI TORINO

Potential of the Reversed-Inject Differential Flow Modulator for Comprehensive Two-dimensional Gas Chromatography in the Quantitative Profiling of Complex Natural Samples

Chiara Cordero*, Carlo Bicchi, Gigi Cobelli, Gianluca Stani
Armando Miliazza, Roger Firor, Matthew Giardina*

***Contact information:**
chiara.cordero@unito.it
matthew_giardina@agilent.com

12th GC×GC Symposium
Fort Worth, Texas USA

Foreword

Basics of Differential Flow Modulation with Reverse Inject dynamics

- ✓system configuration
- ✓principles of operation
- ✓challenges

Complex Vegetal Samples

- ✓compositional characteristics
- ✓sample dimensionality
- ✓investigation strategies: profiling and fingerprinting

System optimization: column settings and performance parameters

- ✓ Peak capacity, selectivity exploitation and information dimensions
- ✓ Model Mixture of volatiles of interest in the F&F field

Real-world samples

- ✓ full quantitative assessment by GC×2GC-FID/MS - Mint and Lavender EOs
- ✓ fingerprinting and classification by chemical signature - Vetiver EOs

Concluding remarks

Foreword

Le.04

A CRITICAL ASSESSMENT OF THE CURRENT STATUS AND POTENTIAL FUTURE OF GC×GC

Matthew Klee[1], *Leonid Blumberg*[2]

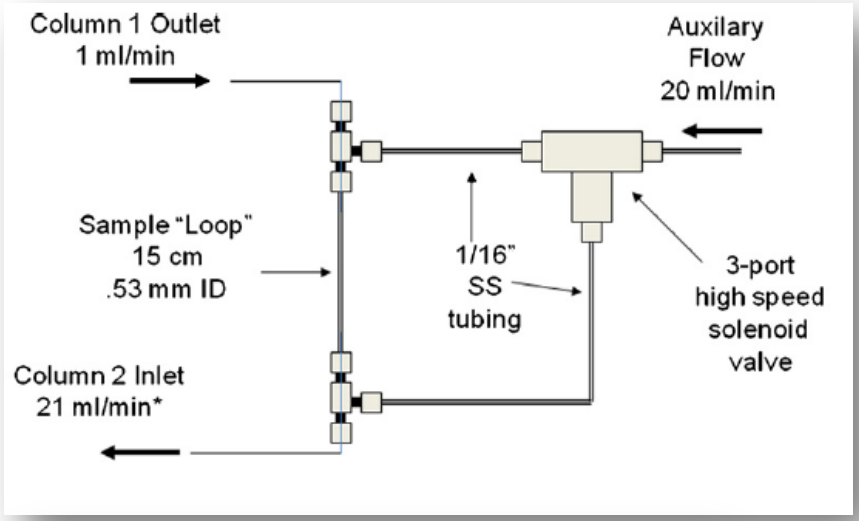
11th GC×GC Symposium
Riva del Garda, Italy

…. Comprehensive multidimensional gas chromatography (CMDGC or GC×GC) is probably the most promising invention in GC since discovery of capillary columns more than half a century ago.

The approach has the potential to provide considerably more sample information in the same timeframe as single dimension GC analyses.

But…

Differential Flow Modulation with "Forward Fill/Flush" dynamics



J.F. Griffith et al. / J. Chromatogr. A 1226 (2012) 116–123

Simplified design J. Seeley *et al.* [1]

- ✓ low operational costs
- ✓ robust hardware

Fully-flexible configurations [2,3]

- ✓adjustable sample loop (length & diameter)
- ✓extended re-injection periods
- ✓column configuration extremely flexible
- ✓compatibility with MS detection

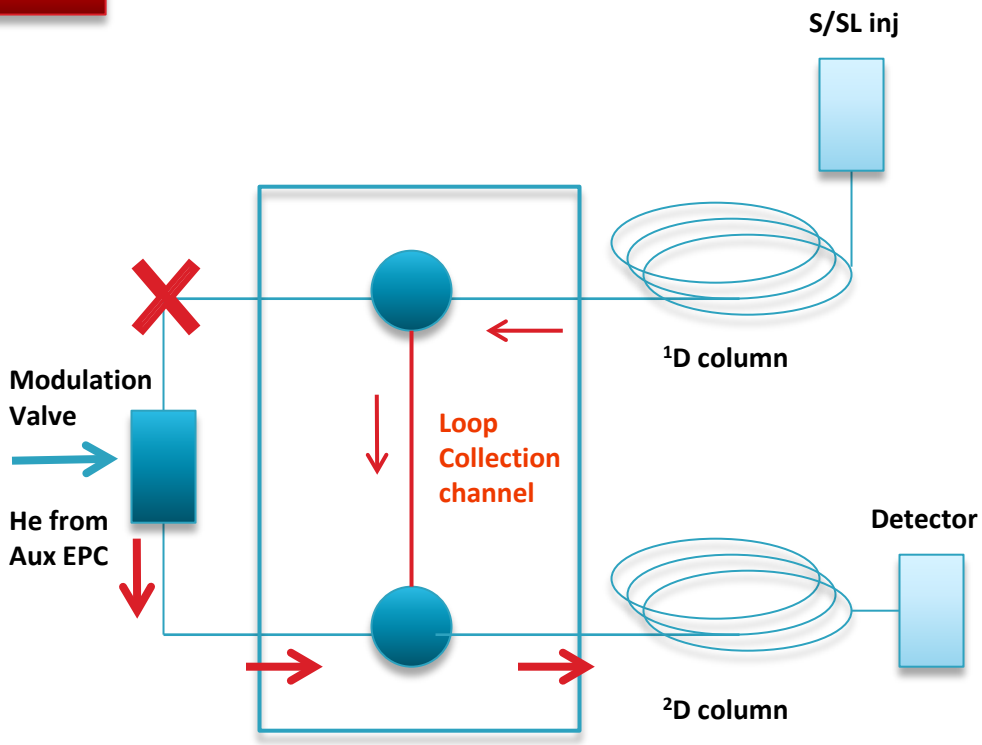
Commercial device - Agilent 2006 [4]

- ✓Capillary Flow Technology (CFT) microfluidic plates
- ✓Forward Fill/Flush (FFF) dynamics [1]
- ✓Sample loop fixed volume
- ✓Operative limitations (columns diameter and volumetric flows)

1. Seeley, J. V.; Micyus, N. J.; McCurry, J. D.; Seeley, S. K. Am. Lab. 2006, 38, 24–26
2. P.Q. Tranchida, F.A Franchina, P. Dugo, L. Mondello. J. Chromatogr A 2014;1359, 271-276
3. P.Q. Tranchida, F.A Franchina, P. Dugo, L. Mondello. J. Chromatogr A 2014;1372, 236-244
4. R.L. Firor, Application Brief 5989-6078EN, Agilent Technologies, 2007

Differential Flow Modulation with "Forward Fill/Flush" dynamics

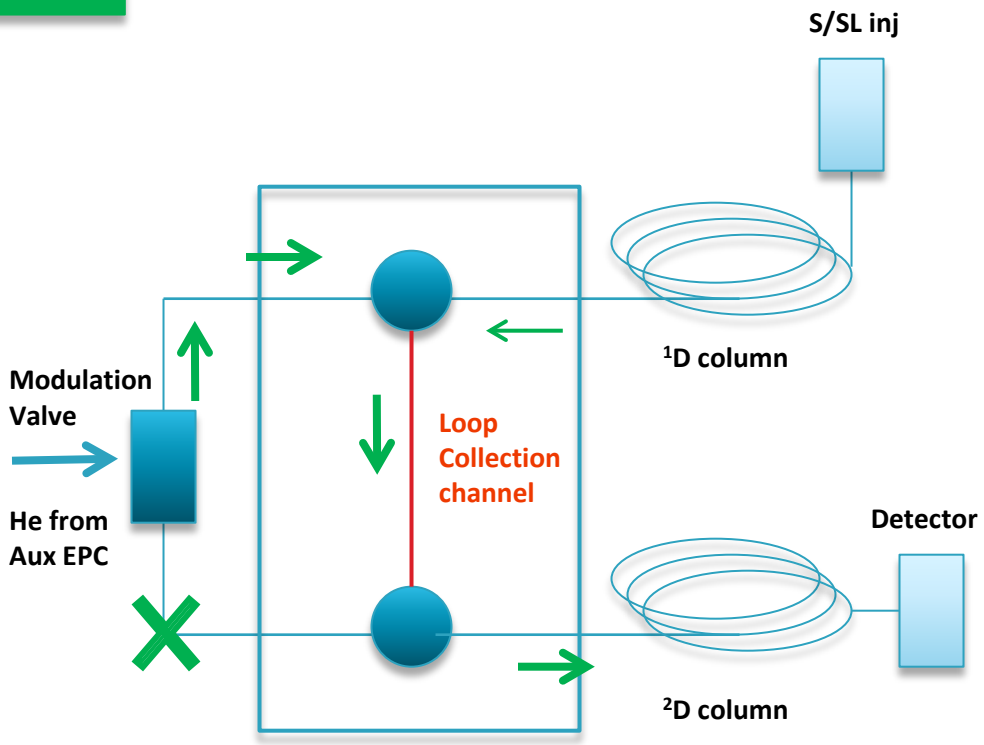
Loading



Adapted from Agilent 5989-9889EN

Differential Flow Modulation with "Forward Fill/Flush" dynamics

Injection



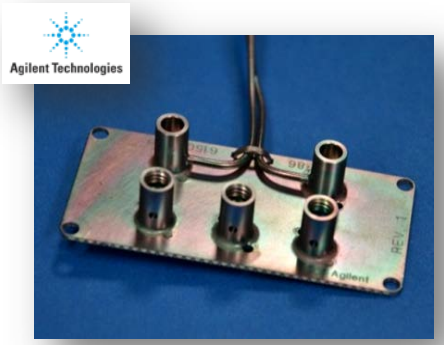
Adapted from Agilent 5989-9889EN

Successful applications

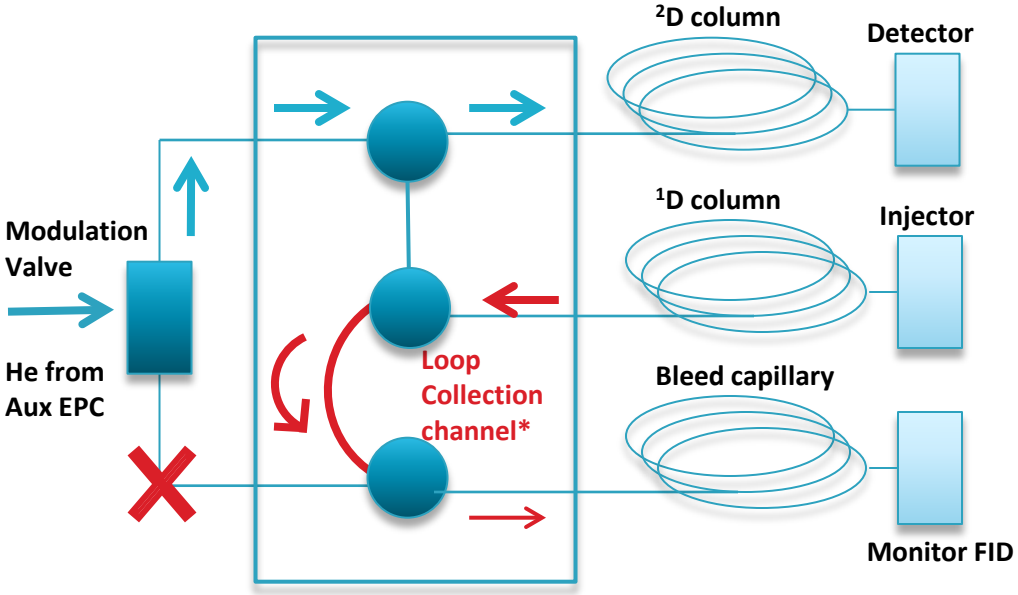
- ✓fatty acids methyl esters [1]
- ✓hydrocarbons in light cycle oils [2]
- ✓ gasoline and kerosene [3]
- ✓volatiles roasted almonds [4]

1. Q. Gu et al. J. Chromatogr. A 1217 (2010) 4448–4453
2. G. Semard et al. J. Chromatogr. A 1218 (2011) 3146–3152
3. J. Krupcík et al. J. Chromatogr. A 1280 (2013) 104– 111
4. P. Manzano et al. J. Sep. Sci. 2014, 37, 675–683

Differential Flow Modulation with "Reverse Fill/Flush" dynamics



Loading

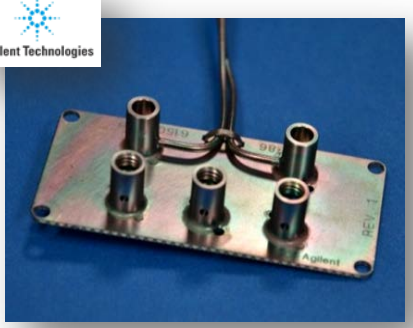


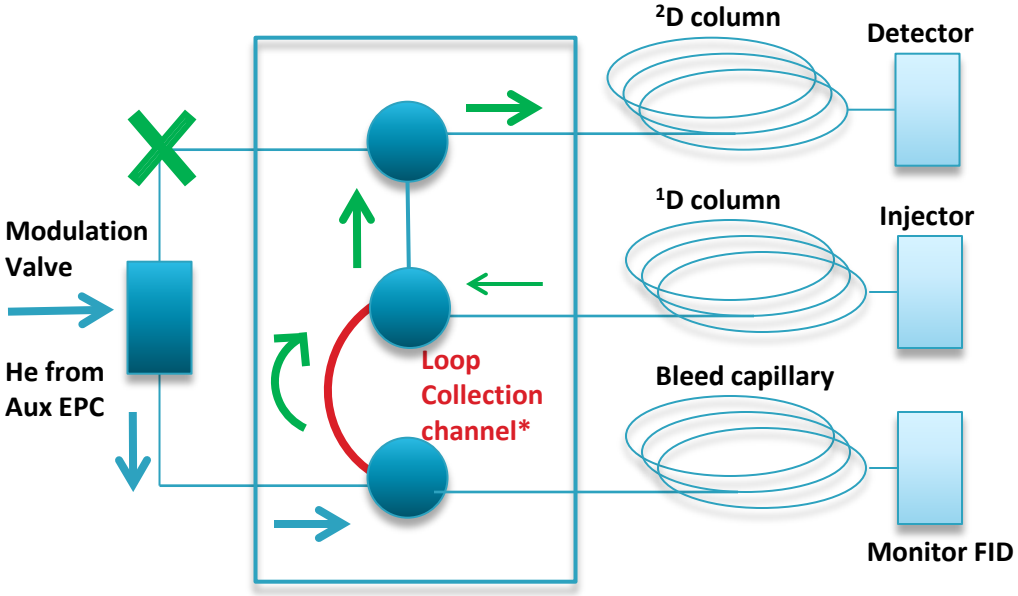
* Rough representation of internal channel

Length and diameter of the restrictor capillary are chosen according to pressure/flow conditions of columns to provide flow equivalent to the output of the first dimension.

Differential Flow Modulation with "Reverse Fill/Flush" dynamics

Injection





* Rough representation of internal channel

Advantages of the RFF dynamics

✓higher efficiency of band re-injection
improved ^{2}D peak-widths
improved ^{2}D peak symmetry

✓ "adjustable" collection channel volume (bleed capillary restriction)

✓better handling of the overloading phenomenon [1,2]

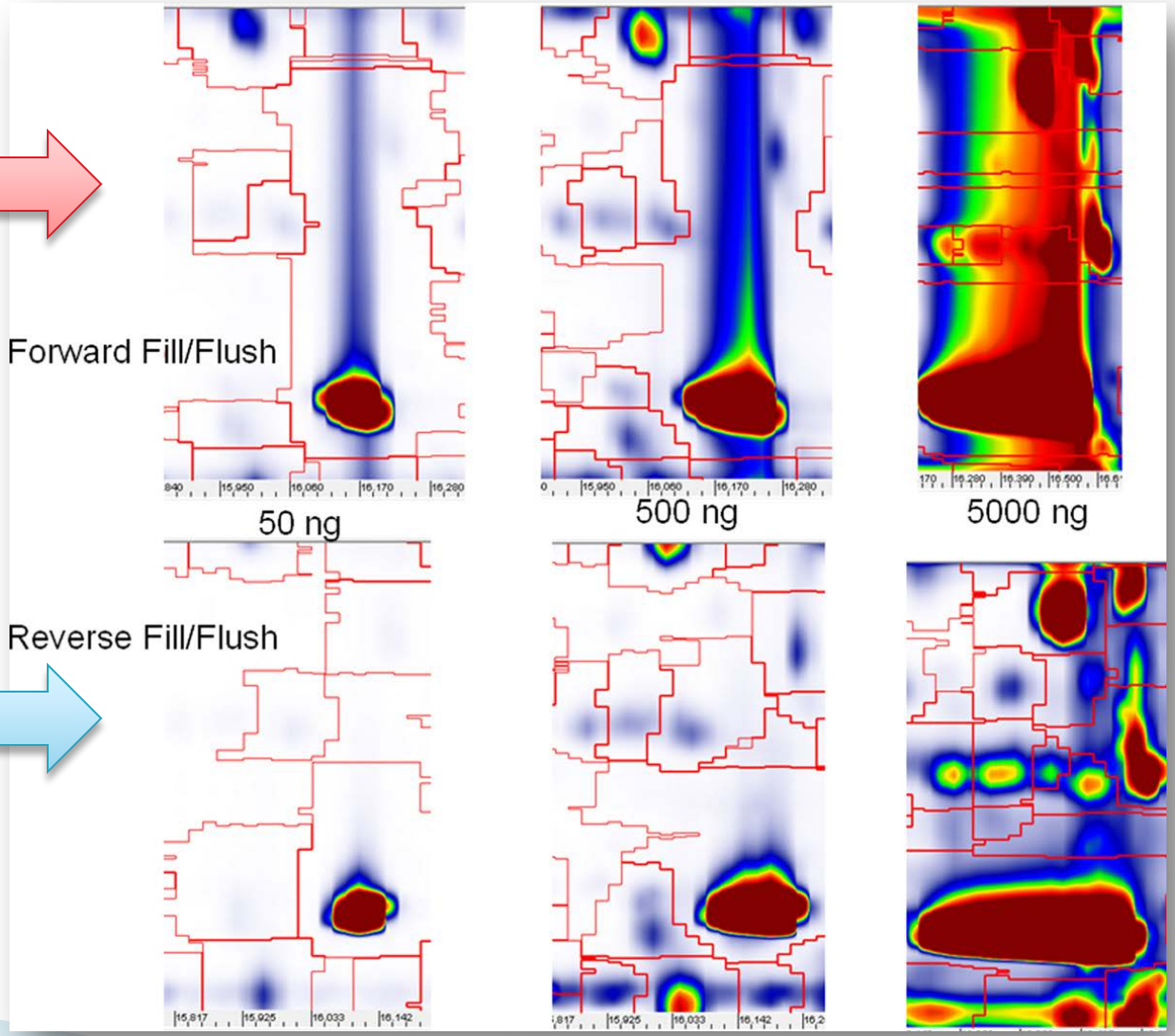
1. J.F. Griffith et al. J. Chromatogr. A 1226 (2012) 116-123
2. C. Duhamel et al. J. Chromatogr. A 1387 (2015) 95–103

Differential Flow Modulation with "Reverse Fill Flush" dynamics

trans-2-hexenyl acetate - variable amount

"Streaking" effect due to collection channel overloading

Non-Gaussian ^{2}D profile "Apparent" overloading of the ^{2}D column



^{2}D peaks of improved symmetry

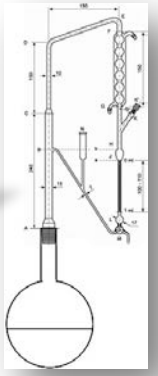
Magnified resolution in the ^{2}D

J.F. Griffith et al. / J. Chromatogr. A 1226 (2012) 116–123

Essential Oils, Extracts and (Volatiles) fractions

Essential oils[1] (EO): product obtained by hydro-, steam- or dry-distillation or by a suitable mechanical process without heating (for *Citrus* fruits*)* of a plant or of some parts of it.

[1] AFNOR NF T 75-006 Feb 1998
[2] European Pharmacopoeia 8th Edn. 2008



Clevenger circulatory distillation apparatus reported in the *European Pharmacopoeia*

Distillates and/or **extracts** selectively concentrate volatiles:

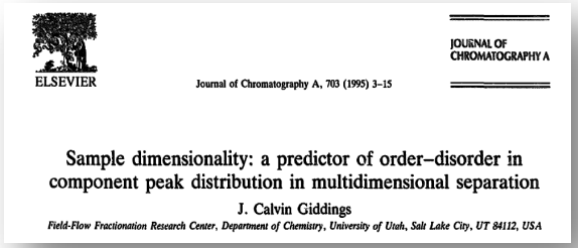
- ✓**Simultaneous Distillation-Extraction** (SDE);
- ✓**Normal pressure or vacuum (hydro-)distillation;**
- ✓**Solvent Assisted Flavour Evaporation** (SAFE);
- ✓**Ultrasound** or **microwave-assisted hydrodistillation**
- ✓**Ultrasound** or **microwave-assisted extraction** (USE, MAE);
- ✓**Selective and/or pressurised** (or accelerated) **solvent extraction** (ASE);
- ✓**Supercritical fluid extraction** (SFE).

Volatiles fraction can be also extracted in the “vapour” phase through headspace (HS) sampling approaches:
Static Headspace (S-HS) extraction, **Dynamic Headspace** (D-HS) and **High Concentration Capacity HS** techniques (SPME, HSSE, MME, MESI etc..).

Complex Vegetal Samples
sample dimensionality - composition

Samples of vegetable origin (EOs, extracts, volatile fractions):
secondary metabolites with common/similar skeleton
common biosynthetic pathways
very variable abundance (from % to µg/Kg)
differing polarity (hydrocarbons, oxygenated derivatives, aromatics etc..)

Samples are characterized by 100-1000 components
Challenge for mono-dimensional separation platforms



ELSEVIER

JOURNAL OF CHROMATOGRAPHY A

Journal of Chromatography A, 703 (1995) 3–15

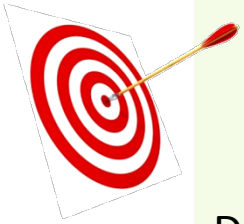
Sample dimensionality: a predictor of order–disorder in component peak distribution in multidimensional separation

J. Calvin Giddings

Field-Flow Fractionation Research Center, Department of Chemistry, University of Utah, Salt Lake City, UT 84112, USA

"… there is some intrinsic property of analytical samples (other than the number m of components) that determines their amenability to multidimensional techniques.
… the key property is related to sample variability…and is defined as sample dimensionality s"
"The parameter s is the number of independent variables that must be specified to identify the components of the sample"

Complex Vegetal Samples
Investigation strategies



Characterize sample composition (detailed profiling)
Quantification of informative analytes
- *(bio)-markers*
- *toxic compounds*
- *regulated substances (e.g. volatile suspected allergens)*
- *potent odorants (e.g. key-aroma compounds)*

Detect adulterations - origin assessment
Classification based on chemical signatures (fingerprinting)

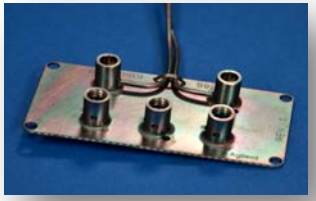
GC×GC with thermal modulators
effective (sensitivity gain and peak capacity)
reliable (identification/quantitation)

But…
Quality Control Laboratories needs
Low operational costs
Simple design and maintenance

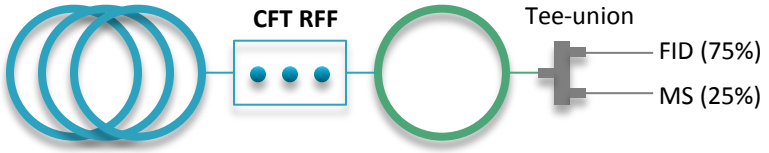
System optimization
column settings

Agilent 7890B GC equipped with 7650A autosampler and 5977A MSD operating in EI mode at 70 eV - FID detector
Scan speed 20,000 amu/s *Etune* option

Reverse-inject differential flow modulator



Prototype consisting of a CFT microfluidic plate
Aux PCM He
Three-way solenoid valve



Capillary columns, unions and non-purged tees were from Agilent

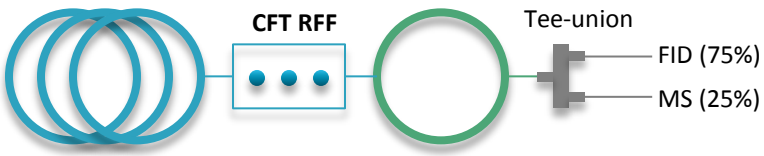
Bleeding capillary was calibrated to counterbalance the ^{1}D column effluent during the filling stage.
To verify the absence of bleeding the capillary was connected to the FID and signal collected during the analytical run.

Raw data was acquired by Enhance MassHunter (Agilent Technologies)

2D data was processed by GC Image® GC×GC Edition Software, Release 2.5 (GC Image, Lincoln NE, USA).

System optimization
column settings

I. "Recommended Configuration"



[1]D - Apolar SE52
30m×0.25mm×0.25µm
He carrier @ **0.35mL/min**

[2]D - Medium polarity OV1701
5.0m×0.25mm×0.25µm
He carrier @ **25mL/min**

Model mixture of volatiles
mono, sesqui and diterpenoids
synthetic odor-active compounds
functionalities: hydrocarbons, alcohols, carbonyls, esters and aromatics
LRI interval (apolar) 900-2350

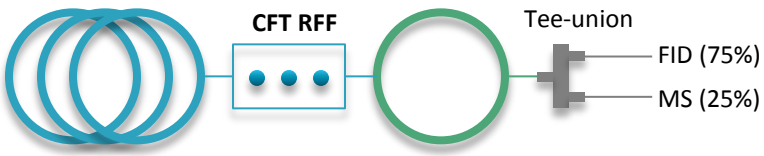
Medium complexity Essential Oils
Mint spp. and Lavender spp. (200-250 peaks)

High complexity Essential Oils
Vetiver (*Chrysopogon zizanioides* L.) (500-600 peaks)

6-Methyl coumarin	Damascenone
α-(Z)- santalol	δ-Damascone
α - Terpineol	Eugenol
α -Damascone (Z)	Eugenyl Acetate
α -Pinene	(E,E)-Farnesol
Amyl Cinnamal	(E,Z)-Farnesol
Anethole	Geranyl Acetate
Benzaldehyde	Hexadecanolactone
Benzyl Alcohol	Hexil Cinnamal (E)
Benzyl Benzoate	Isoeugenol (E)
Benzyl Salicylate	Isoeugenyl Acetate
β-(Z)-santalol	Limonene
β-Caryophillene	Linalool
β-Damascone (Z)	Linalyl Acetate
β-Pinene	Menthol
Camphor	Methyl Salycilate
Carvone	Salicylaldehyde
Cinnamal	Sclareol
Cinnamyc Alcohol	Terpinolene
Citronellol	Vanillin
Coumarin	

System optimization
column settings

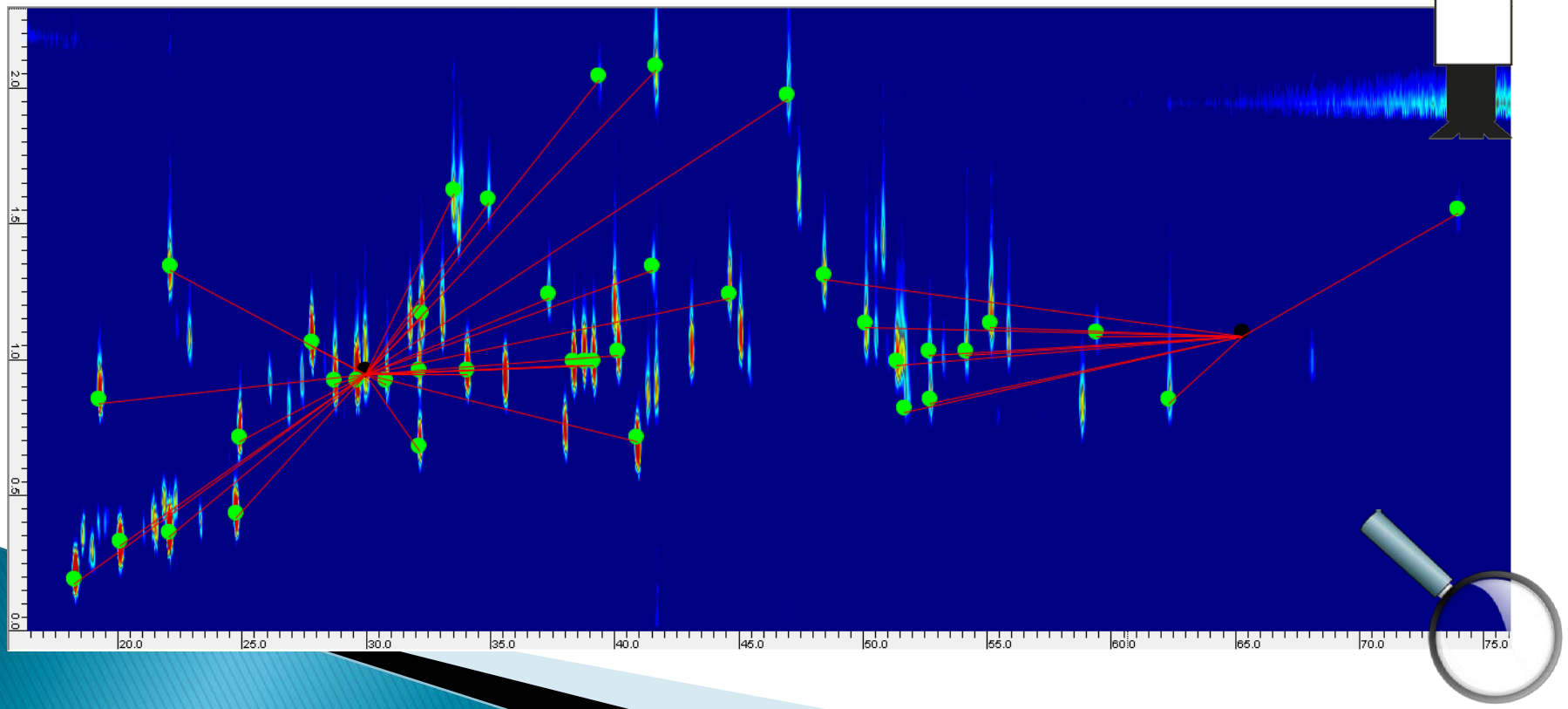
I. "Recommended Configuration"



^{1}D - Apolar SE52
30m×0.25mm×0.25µm
He carrier @ **0.35mL/min**

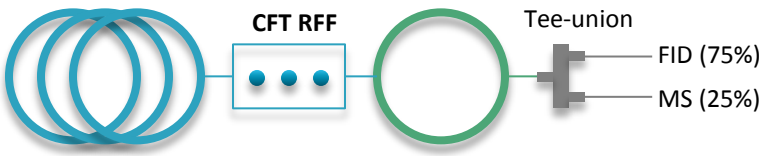
^{2}D - Medium polarity OV1701
5.0m×0.25mm×0.25µm
He carrier @ **25mL/min**

Oven programming
80°C(2') to 280°C(10') @ 3°C/min
Modulation period: 2.5 s
Injection: 0.11 s
Analysis time 75' (last eluted *sclareol*)
Few critical pairs



System optimization
column settings

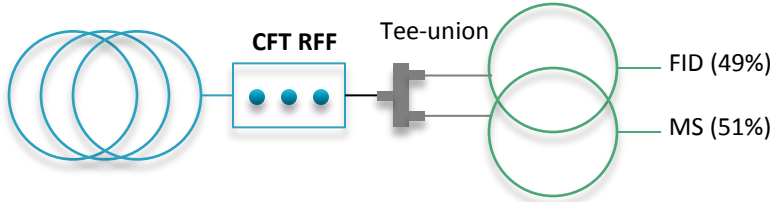
I. "Recommended Configuration"



^{1}D - Apolar SE52
30m×0.25mm×0.25µm
He carrier @ **0.35 mL/min**

^{2}D - Medium polarity OV1701
5.0m×0.25mm×0.25µm
He carrier @ **25 mL/min**

II. Alternative Configuration ApMp1



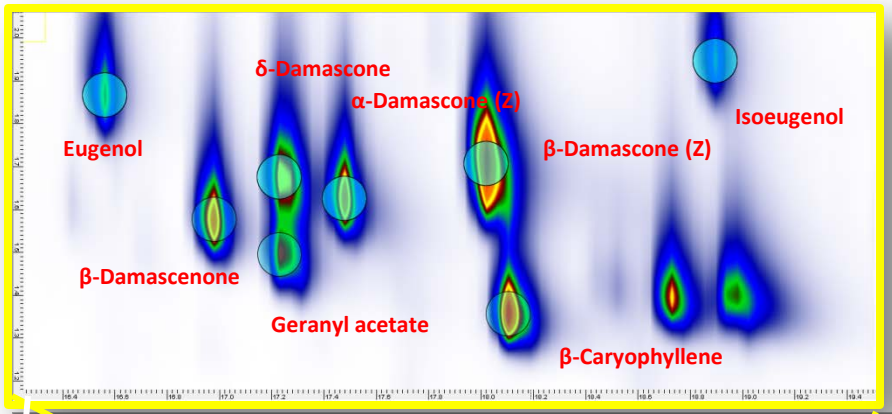
^{1}D - Apolar SE52
10m×0.10mm×0.10µm
He carrier @ **0.40 mL/min**

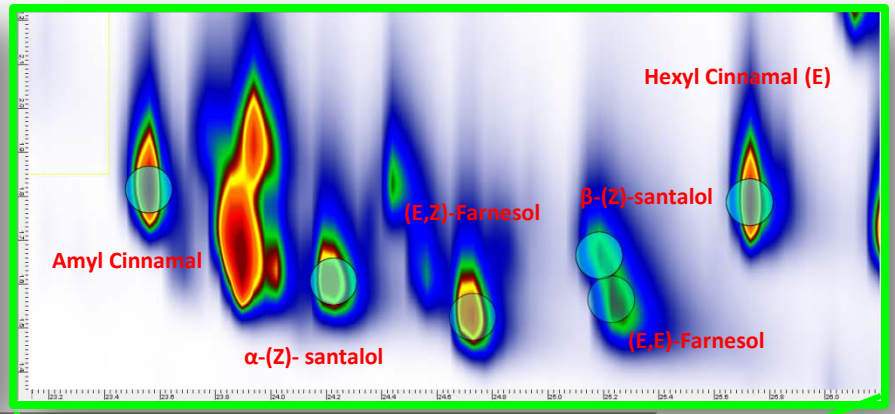
^{2}D - Medium polarity OV1701
two parallel 1.0m×0.10mm×0.10µm
He carrier @ **6 mL/min**

Added features:
- ✓^{1}D narrow-bore column
- ✓two ^{2}D columns (doubled loading capacity - halved flow resistance)
- ✓^{2}D flows compatible to MS

System optimization
column settings

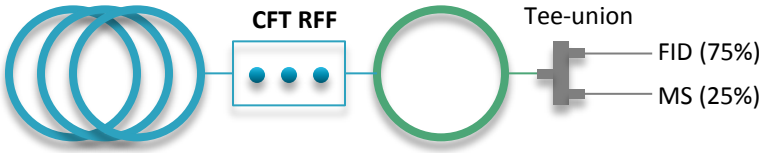
Oven programming
50°C(1') to 280°C(10') @ 5°C/min
Modulation period: 2.5 s
Injection: 0.11 s
Analysis time 35' (last eluted *sclareol*)
Few critical pairs





System optimization
column settings

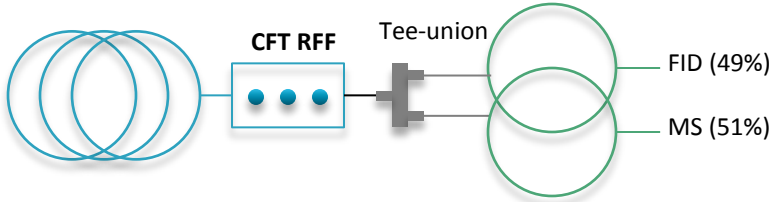
I. "Recommended Configuration"



^{1}D - Apolar SE52
30m×0.25mm×0.25µm
He carrier @ **0.35 mL/min**

^{2}D - Medium polarity OV1701
5.0m×0.25mm×0.25µm
He carrier @ **25 mL/min**

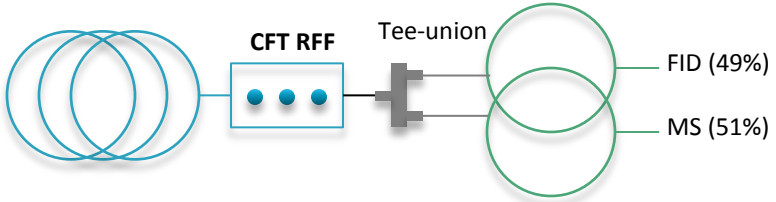
II. Alternative Configuration ApMp1



^{1}D - Apolar SE52
10m×0.10mm×0.10µm
He carrier @ **0.40 mL/min**

^{2}D - Medium polarity OV1701
two parallel 1.0m×0.10mm×0.10µm
He carrier @ **6 mL/min**

III. Alternative Configuration ApMp2



^{1}D - Apolar OV1
10m×0.10mm×**0.40µm**
He carrier @ **0.40 mL/min**

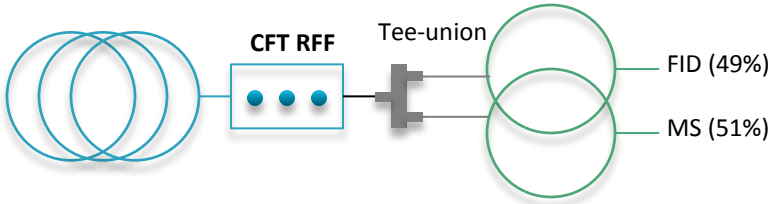
^{2}D - Medium polarity OV1701
two parallel 1.5m×0.10mm×0.10µm
He carrier @ **4 mL/min**

Added features:
✓thicker film in the ^{1}D
✓longer ^{2}D columns

Expectations:
✓higher overall sensitivity
✓lower carries flows in the ^{2}D
✓possibility to increase MP

System optimization
column settings

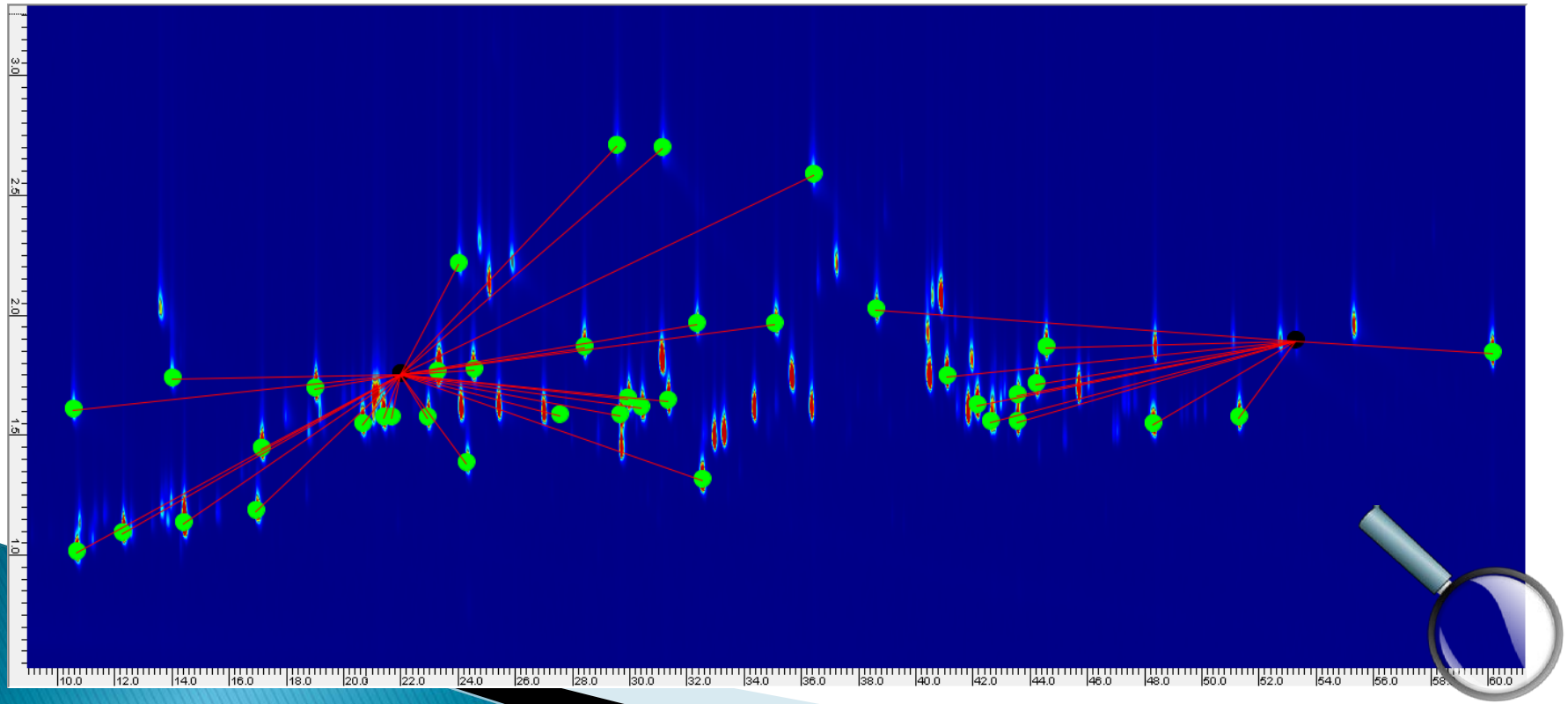
III. Alternative Configuration ApMp2



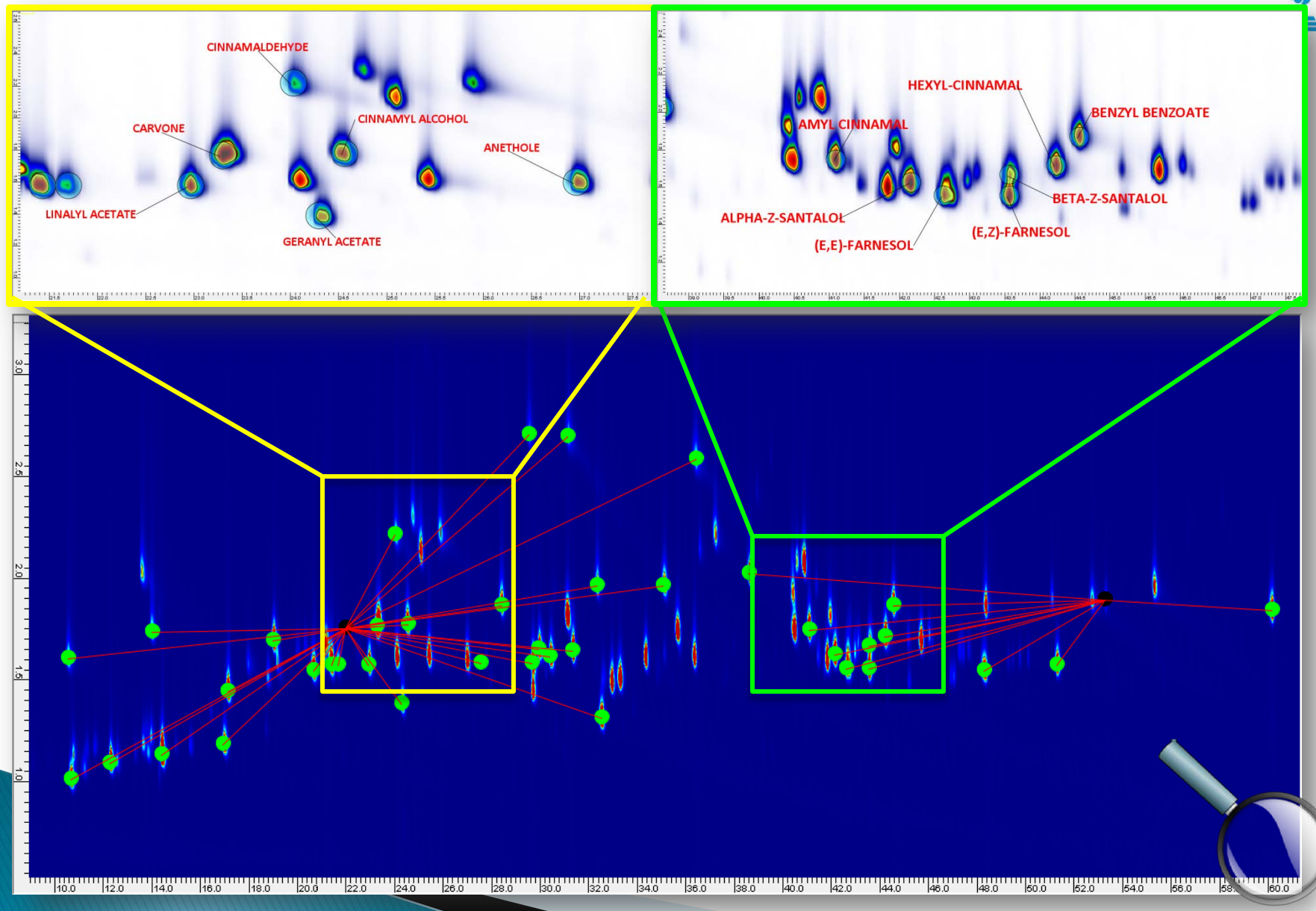
^{1}D - Apolar OV1
10m×0.10mm×**0.40µm**
He carrier @ **0.40 mL/min**

^{2}D - Medium polarity OV1701
two parallel 1.5m×0.10mm×0.10µm
He carrier @ **4 mL/min**

Oven programming
50°C(1') to 280°C(10') @ 3°C/min
Modulation period: 4 s
Injection: 0.11 s
Analysis time 60' (last eluted *sclareol*)
Fully-resolved pattern

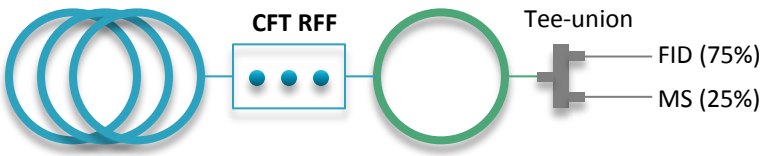


System optimization
column settings



System optimization
column settings

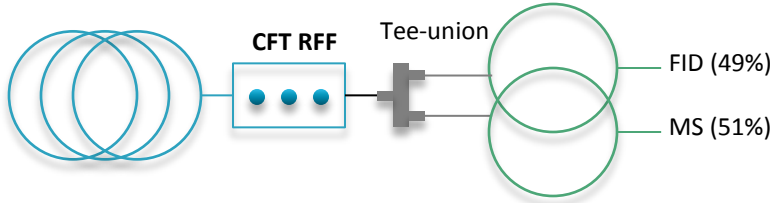
I. "Recommended Configuration"



^{1}D - Apolar SE52
30m×0.25mm×0.25µm
He carrier @ **0.35 mL/min**

^{2}D - Medium polarity OV1701
5.0m×0.25mm×0.25µm
He carrier @ **25 mL/min**

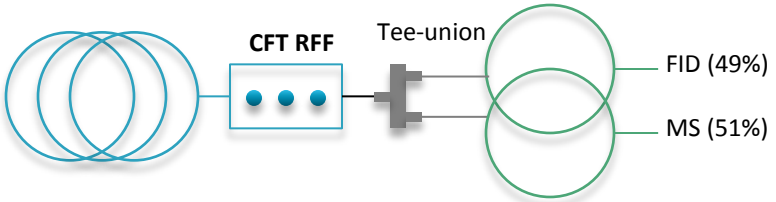
II. Alternative Configuration ApMp1



^{1}D - Apolar SE52
10m×0.10mm×0.10µm
He carrier @ **0.40 mL/min**

^{2}D - Medium polarity OV1701
two parallel 1.0m×0.10mm×0.10µm
He carrier @ **6 mL/min**

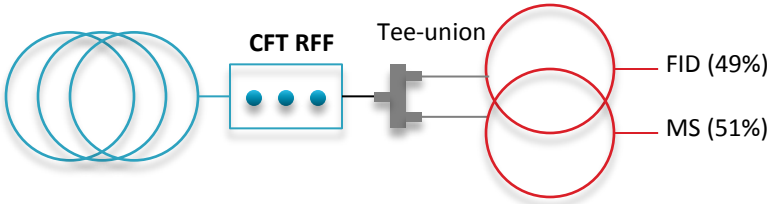
III. Alternative Configuration ApMp2



^{1}D - Apolar OV1
10m×0.10mm×**0.40µm**
He carrier @ **0.40 mL/min**

^{2}D - Medium polarity OV1701
two parallel 1.5m×0.10mm×0.10µm
He carrier @ **4 mL/min**

IV. Alternative Configuration ApP3



^{1}D - Apolar OV1
10m×0.10mm×**0.40µm**
He carrier @ **0.40 mL/min**

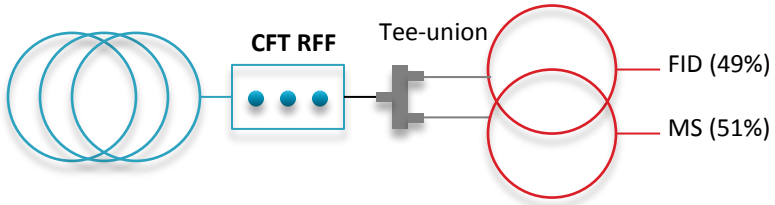
^{2}D - Polar PEG
two parallel 1.5m×0.10mm×0.10µm
He carrier @ **4 mL/min**

Added features:
✓higher polarity ^{2}D

Expectations
✓improved "orthogonality"
✓improved ^{2}D peak-widths
✓reduced analysis time (faster rates)

System optimization
column settings

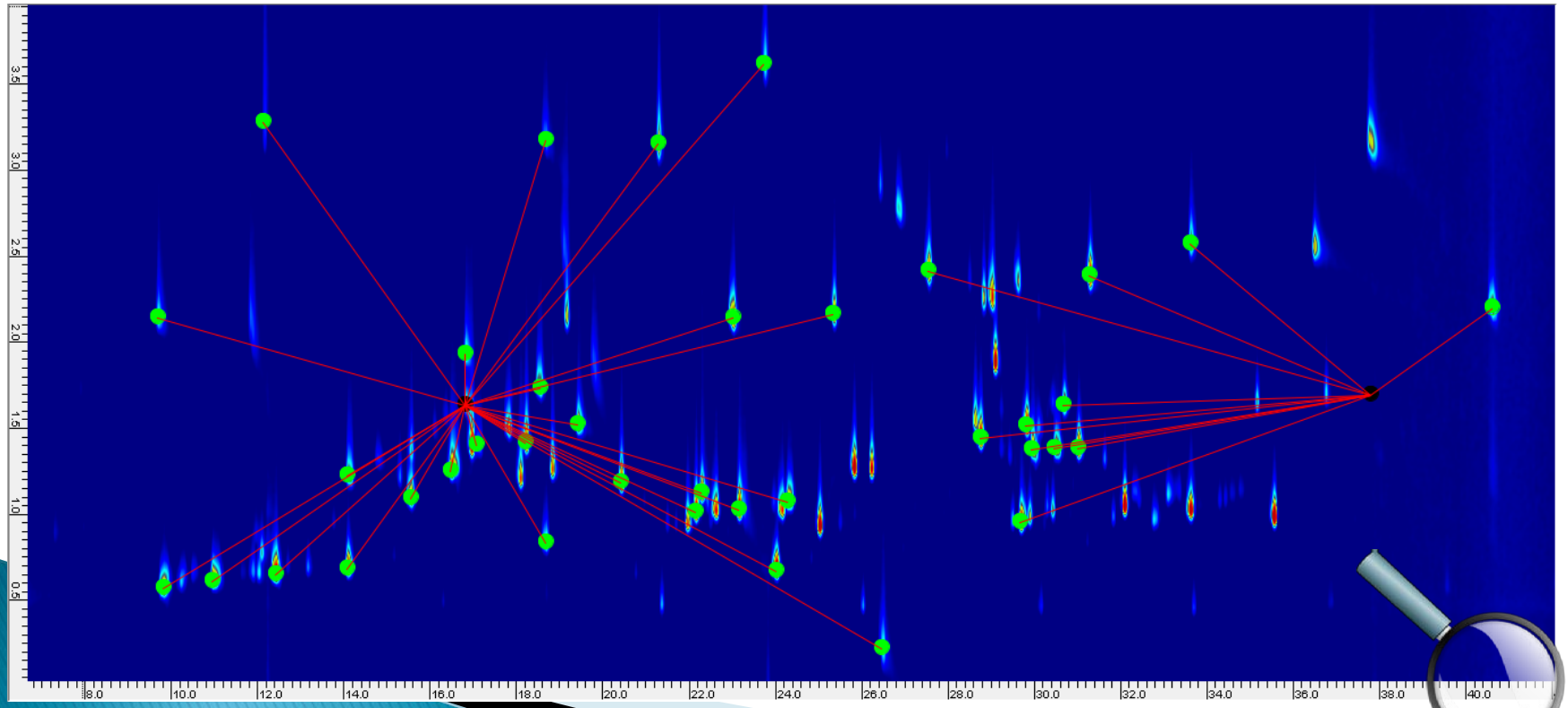
IV. Alternative Configuration ApP3



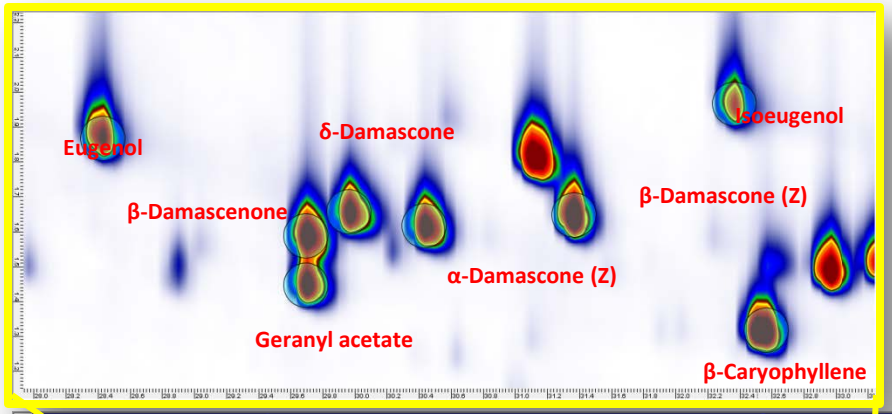
^{1}D - Apolar OV1
10m×0.10mm×**0.40µm**
He carrier @ **0.40 mL/min**

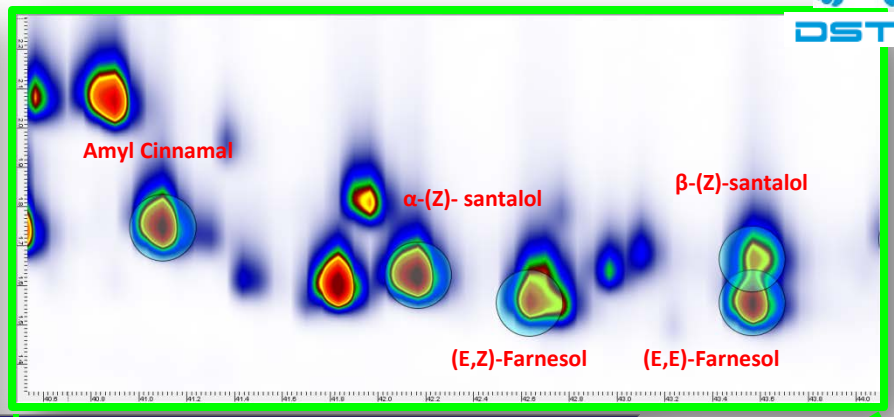
^{2}D - Polar PEG
two parallel 1.5m×0.10mm×0.10µm
He carrier @ **4 mL/min**

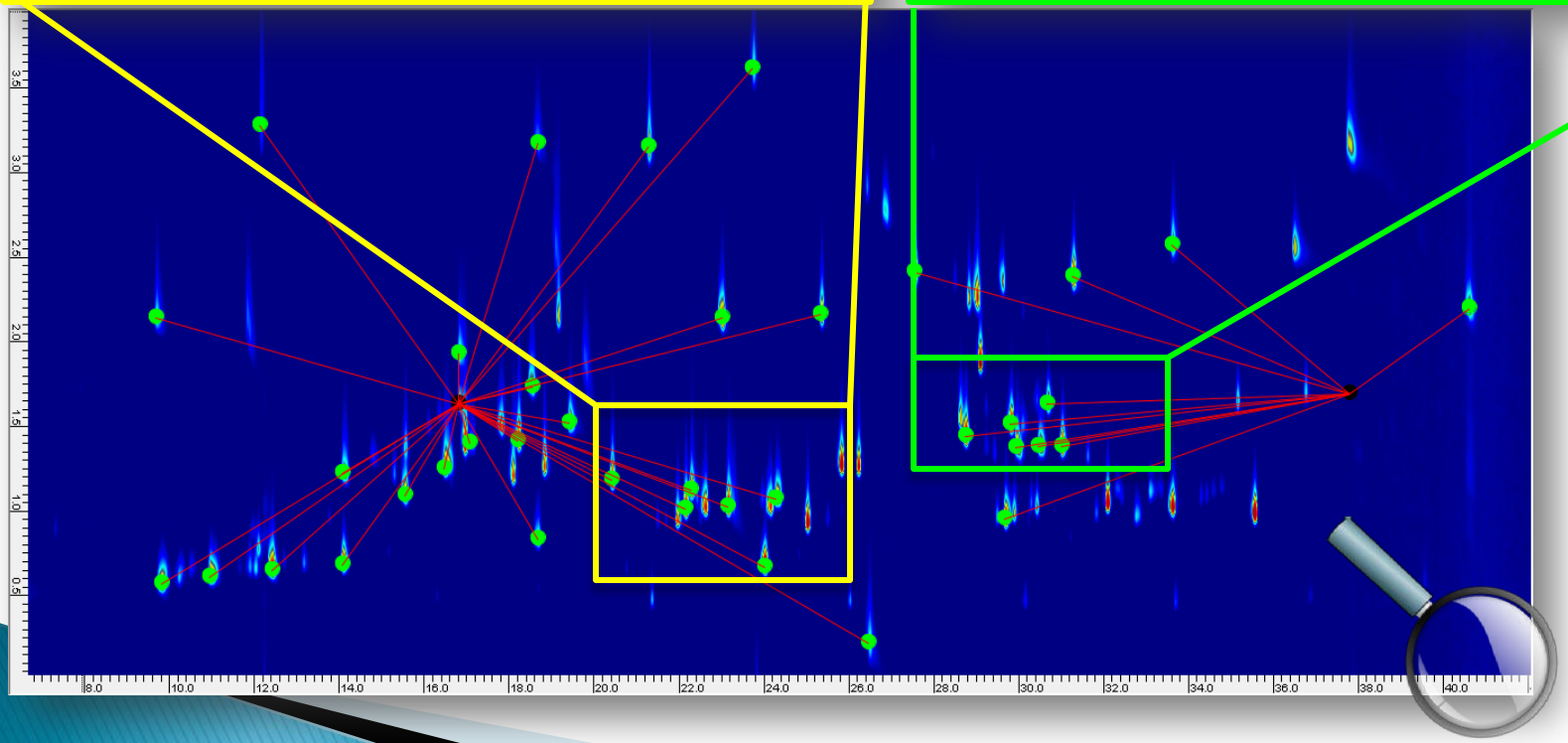
Oven programming
70°C(1') to 280°C(10') @ 5°C/min
Modulation period: 4 s
Injection: 0.11 s
Analysis time 40 min (last eluted *sclareol*)
Fully-resolved pattern



System optimization
column settings

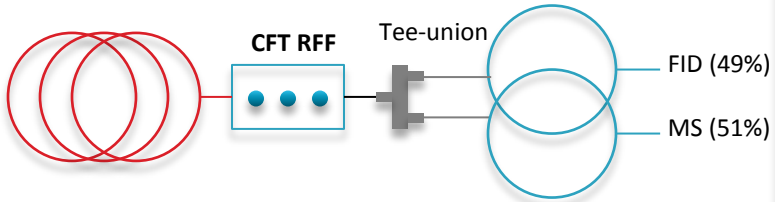






System optimization
column settings

V. Alternative Configuration PMp4

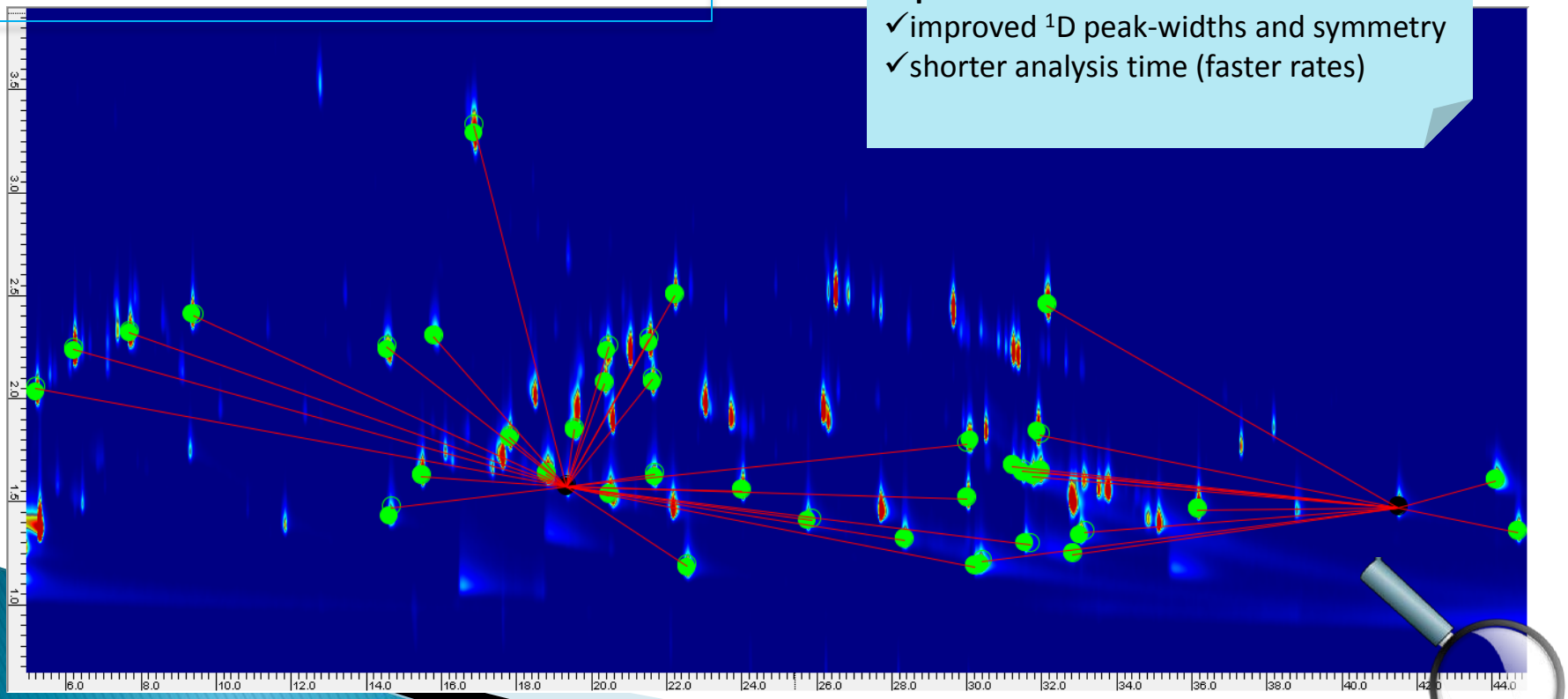


^{1}D - Polar PEG
10m×0.10mm×0.10µm
He carrier @ **0.40 mL/min**

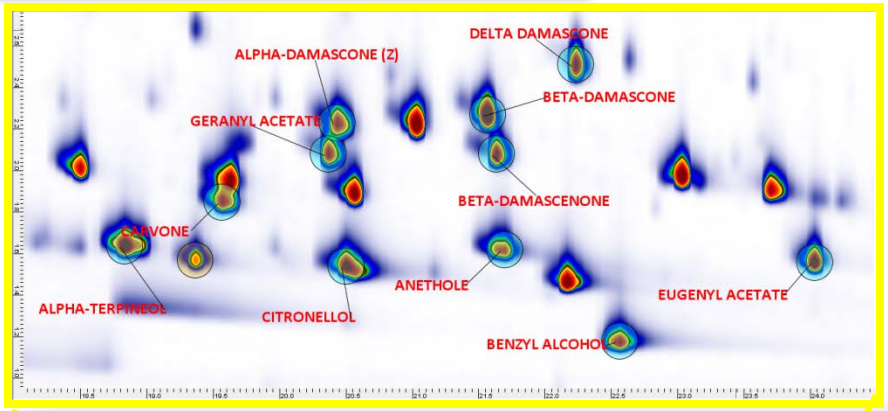
^{2}D - Medium Polarity OV1701
two parallel 1.5m×0.10mm×0.10µm
He carrier @ **4 mL/min**

Added features:
✓^{1}D volatility/polarity driven separation

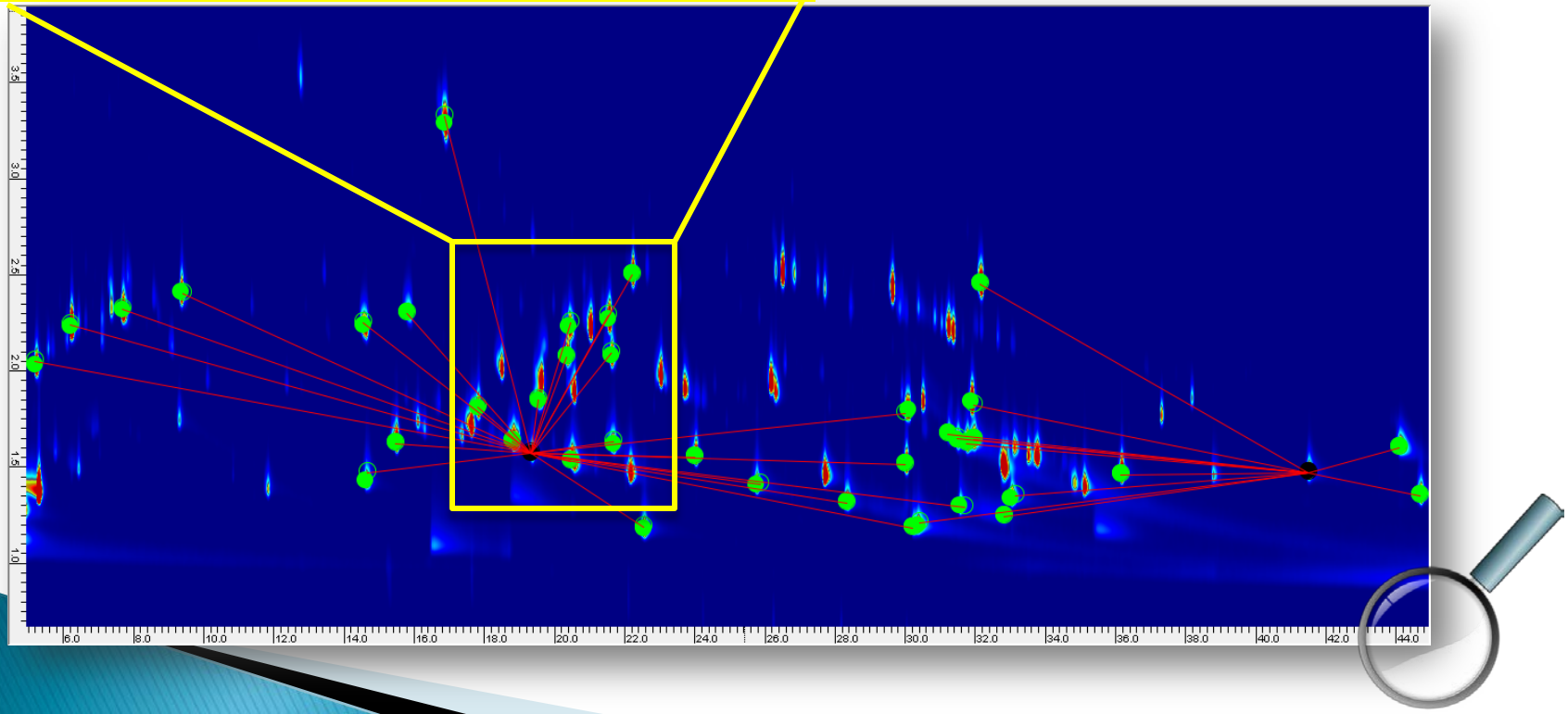
Expectations
✓improved ^{1}D peak-widths and symmetry
✓shorter analysis time (faster rates)



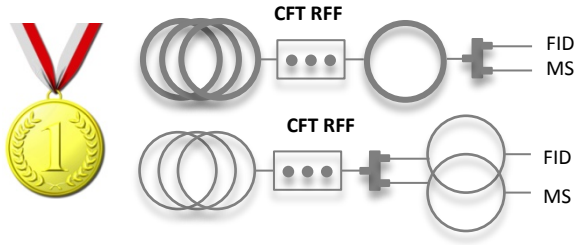
System optimization
column settings



Oven programming
50°C(1') to 260°C(10') @ 5°C/min
Modulation period: 4 s
Injection: 0.11 s
Analysis time 44 min (last eluted *benzyl salicilate*)
Fully-resolved pattern



System optimization
performance evaluation



Performance parameters

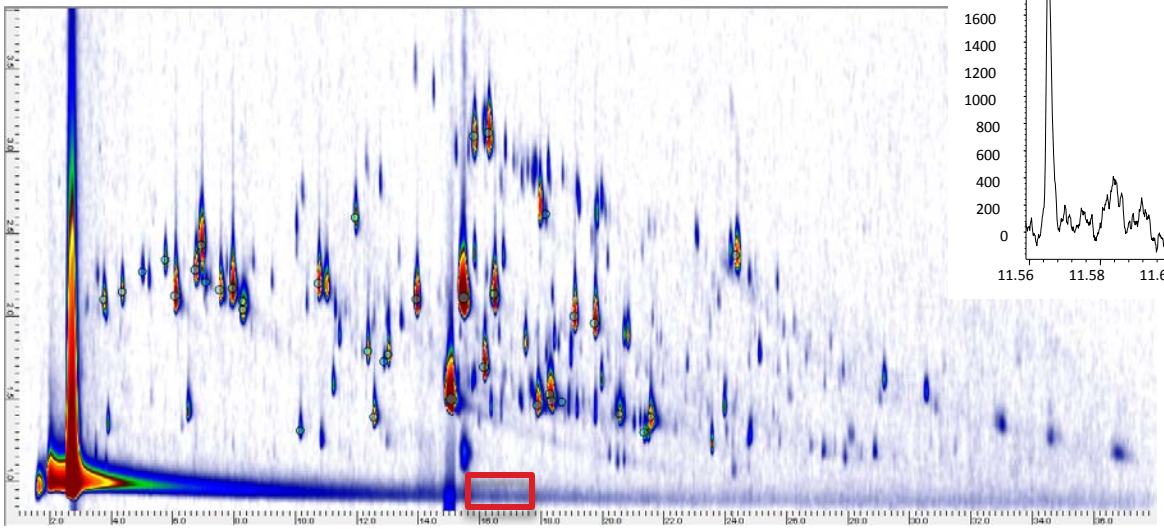
Re-injection pulse width (σ^2_i) [1]

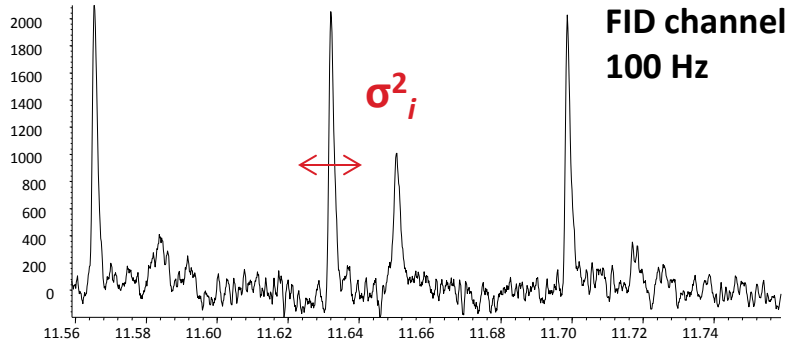
Net separation measure ($S_{GC\times GC}$) [2]

Modulation Ratio (M_R) [3]

Separation space used [4]

Re-injection pulse width (σ^2_i)

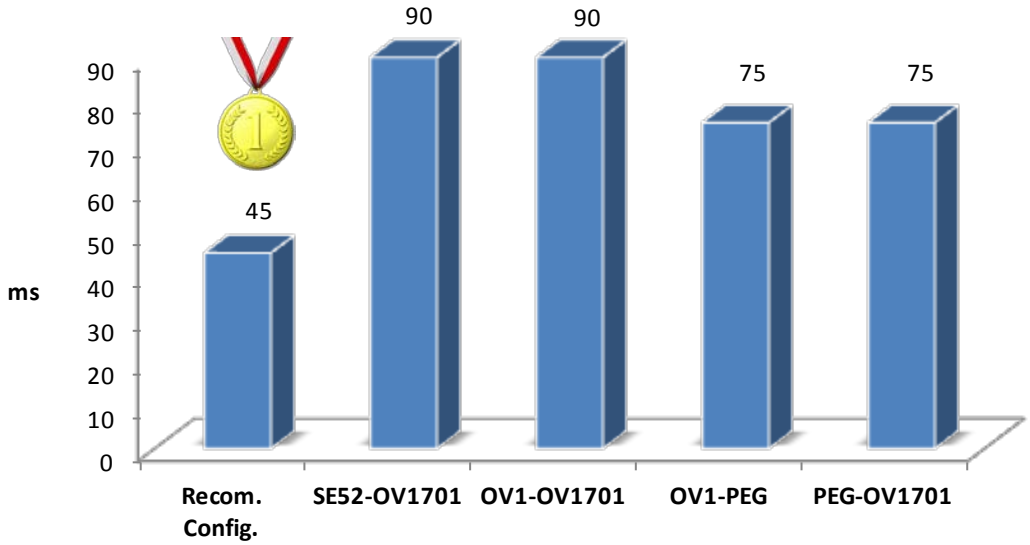




Lavender EO Alt. Conf. PMp4 (PEG-OV1701) - Oven 50°C(1') to 260°C(10') @ 5°C/min
Modulation period: 4 s - Injection: 0.11 s - Analysis time 44 min

1. M. Klee et al. (2015) J. Chromatogr. A 1383, 151-159
2. L. M. Blumberg (2003) J. Chromatogr. A 985, 29 – 38
3. W. Khummueng et al. (2006) Anal. Chem. 78, 4578 – 4587
4. D. Ryan et al. (2005) J. Chromatogr. A. 1071, 47 – 53

System optimization
performance evaluation



Re-injection pulse width (σ^2_i)

Very effective re-injection bands geometry of the CFT plate re-injection dynamics (RFF)

Values are in agreement with those reported by Duhamel et al. [1]

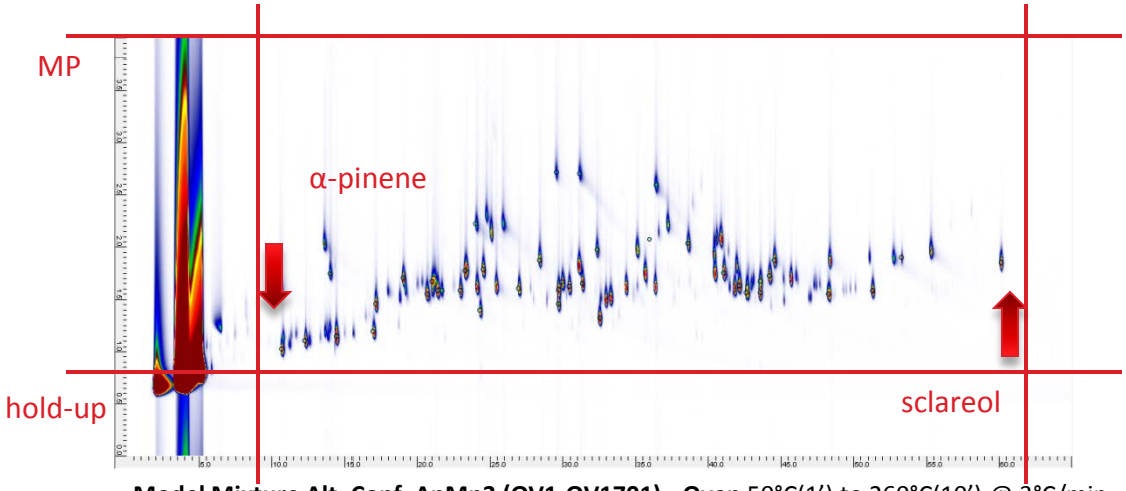
Net separation measure ($S_{GC\times GC}$)

$S = \Delta t\ \delta_{av}$

$S_{GC\times GC} = S_1 * S_2$

S_1 first and last eluting 2D-peak

S_2 2D hold-up time and MP

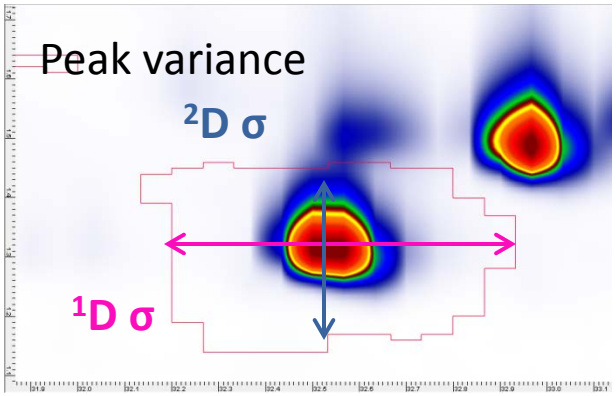


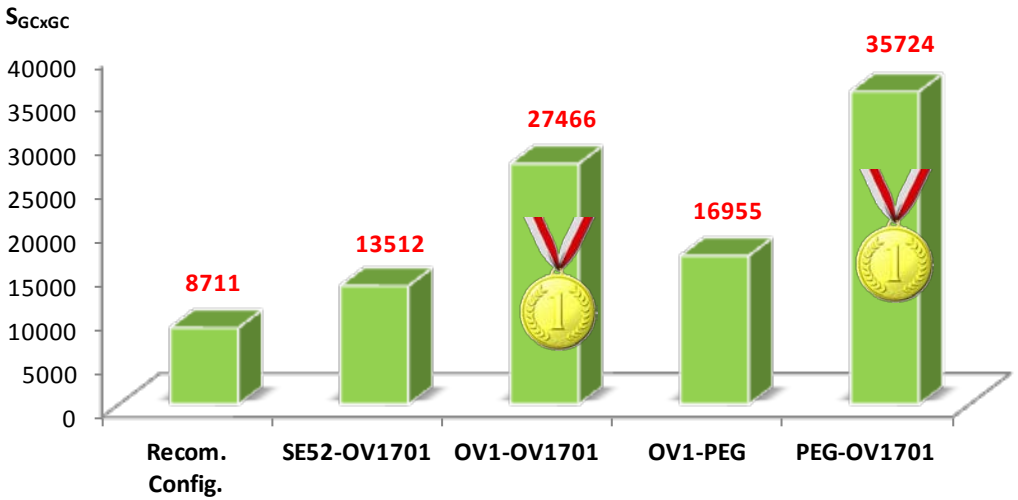
Model Mixture Alt. Conf. ApMp3 (OV1-OV1701) - Oven 50°C(1') to 260°C(10') @ 3°C/min
Modulation period: 4 s - Injection: 0.11 s - Analysis time 60 min

1. C. Duhamel et al. J. Chromatogr. A 1387 (2015) 95–103

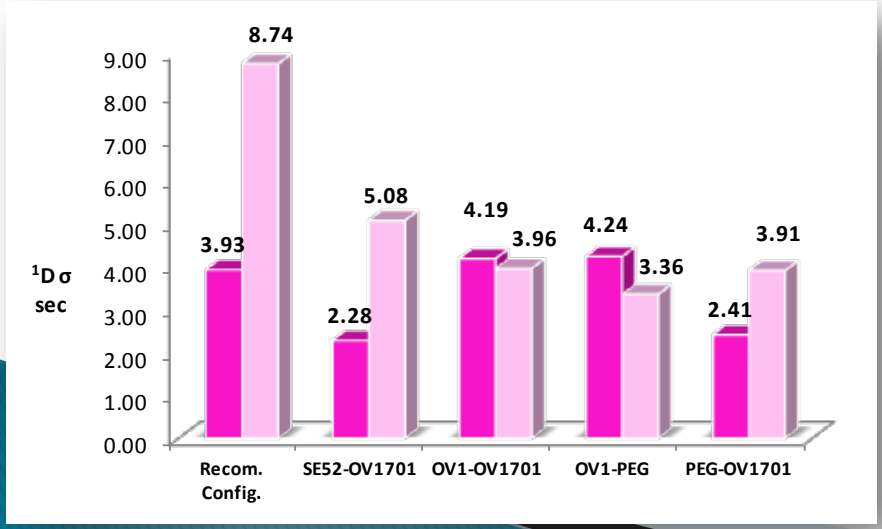
System optimization *performance evaluation*

Net separation measure ($S_{GC\times GC}$)

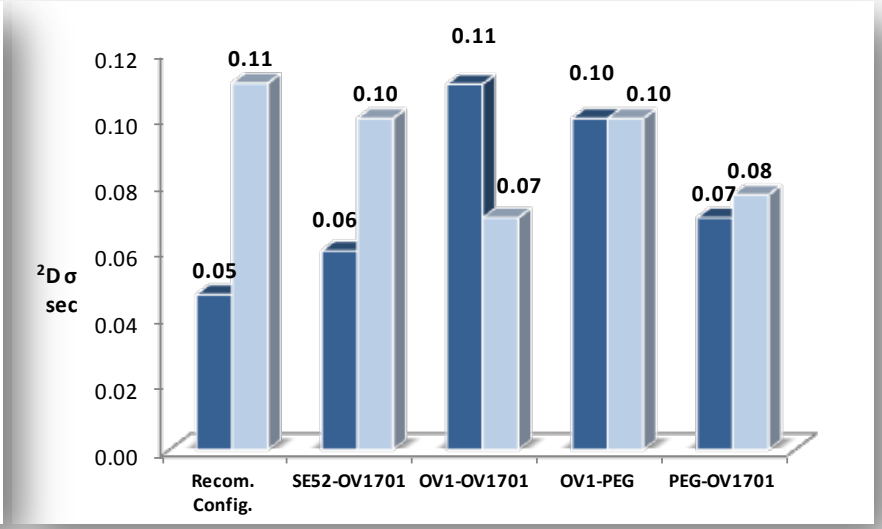




^{1}D σ (s) first and last eluted peak



^{2}D σ (s) first and last eluted peak



System optimization *performance evaluation*

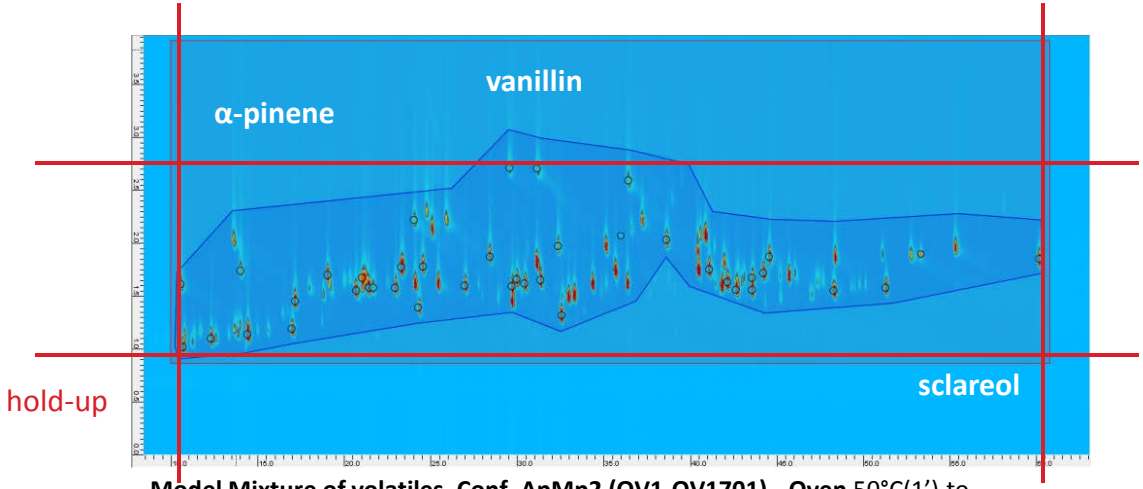
Separation space used [1]

degree of correlation between dimensions

✓nature of the stationary phases

✓changes of selectivity operated by temperature programming

1. W. Khummueng et al. (2006) Anal. Chem. 78, 4578 – 4587



Model Mixture of volatiles Conf. ApMp2 (OV1-OV1701) - Oven 50°C(1') to 280°C(10') @ 3°C/min Modulation period: 4 s Injection: 0.11 s Analysis time 50 min

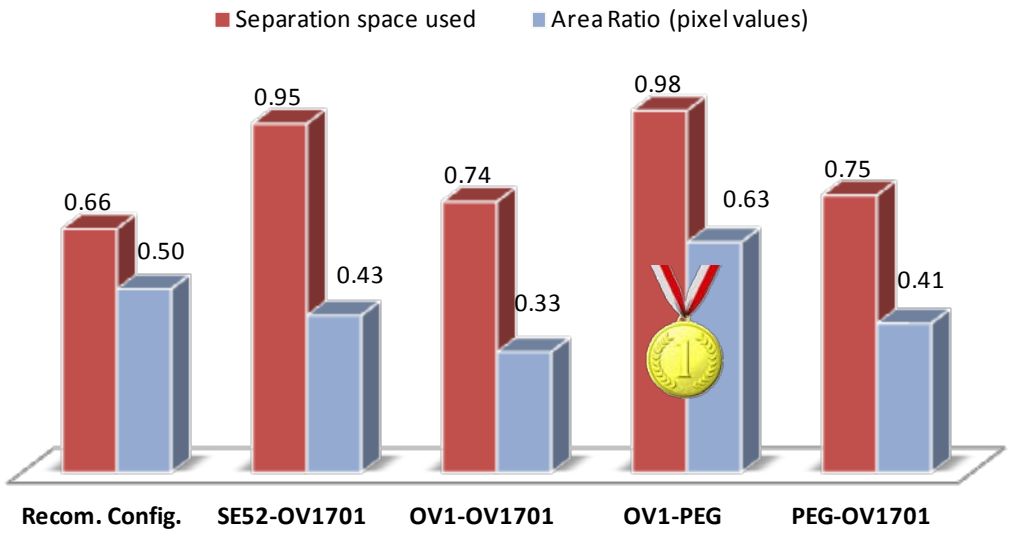
Separation space used [1]

2D area (s*s) occupied by solute separation (between the first and the last eluted analytes in both dimensions) and the 2D available area above the hold-up time

Area ratio (pixels)

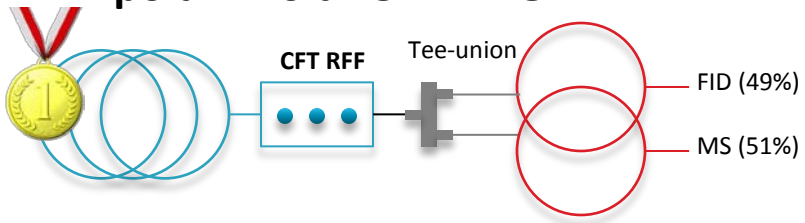
pixel-based area ratio

boundary area (pixels) around the elution pattern (blue boundary in **Figure**) and the available retention time area



Real-world samples

IV. Apolar - Polar OV1-PEG



^{1}D - Apolar OV1
10m×0.10mm×**0.40µm**
He carrier @ **0.40 mL/min**

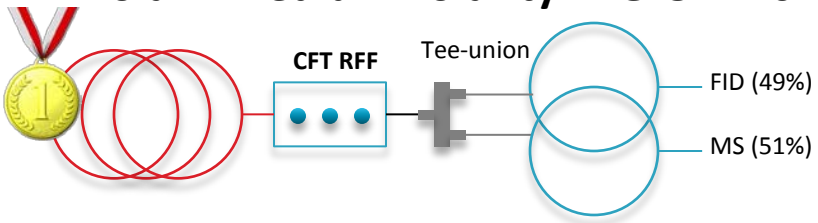
^{2}D - Polar PEG
two parallel 1.5m×0.10mm×0.10µm
He carrier @ **4 mL/min**

Lowest degree of correlation
2D peaks spreading maximized

500-800 peaks

Chrysopogon zizanioides L. (vetiver) EOs
Different "types" *Haiti*, *Java*, *Brazil* & *Bourbon*

V. Polar - Medium Polarity PEG-OV1701



^{1}D - Polar PEG
10m×0.10mm×0.10µm
He carrier @ **0.40 mL/min**

^{2}D - Medium Polarity OV1701
two parallel 1.5m×0.10mm×0.10µm
He carrier @ **4 mL/min**

Highest peak-capacity($S_{GC\times GC}$)
Very high efficiency for polar analytes

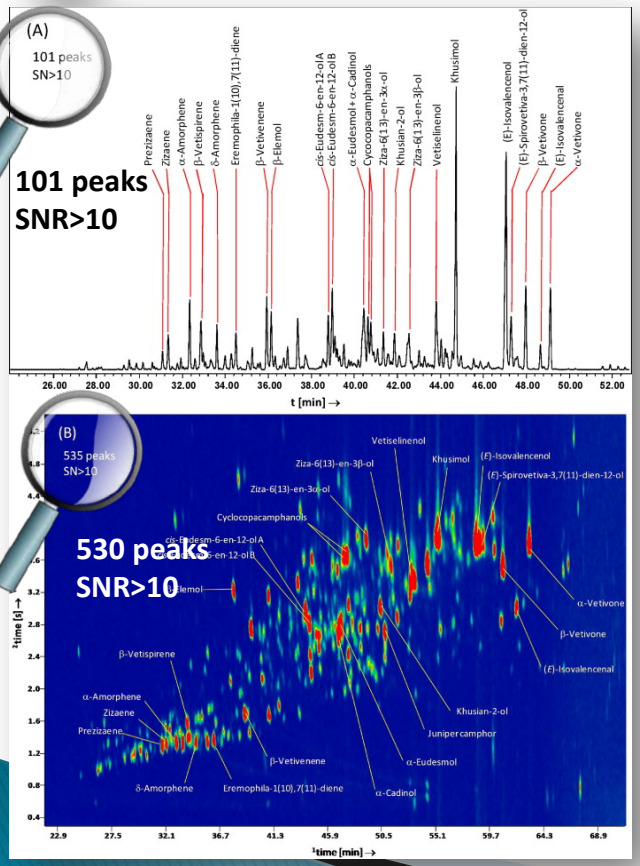
200-300 peaks

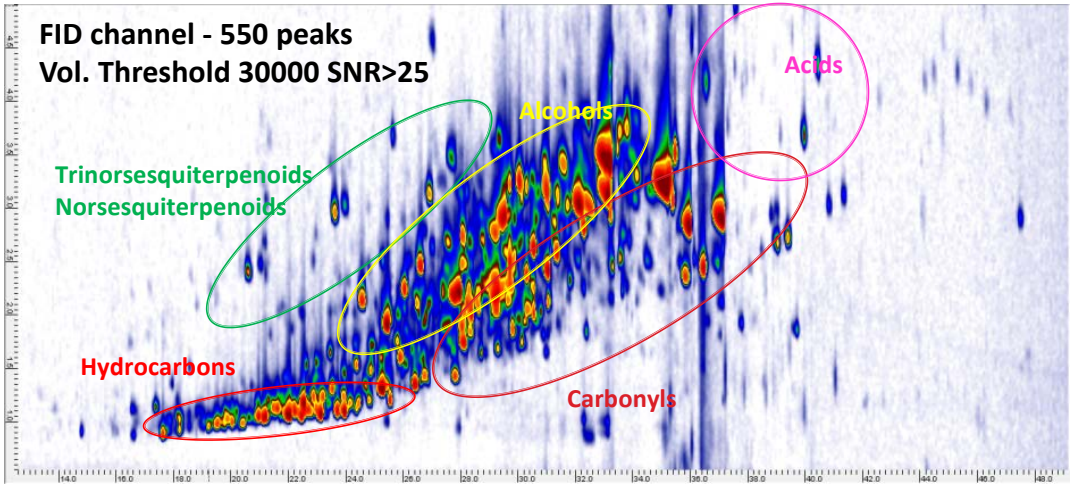
Mentha x *piperita* L. (peppe
Mentha spicata L. (spearmint)

Lavandula angustifolia Mill. (lavender)

Real-world samples

Chrysopogon zizanioides L. (vetiver) EOs
Different "types" *Haiti*, *Java*, *Brazil* & *Bourbon*





Haiti type vetiver EO Conf. ApP3 (OV1-PEG) - Oven 120°C(2') to 280°C(10') @ 2.5°C/min
Modulation period: 5s Injection: 0.11 s Analysis time 45 min

Chemical signatures

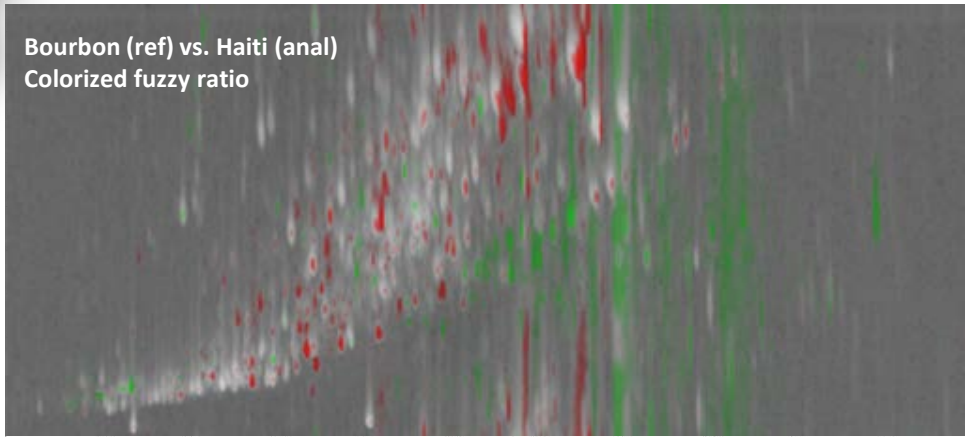
2D peaks-different chemical entities

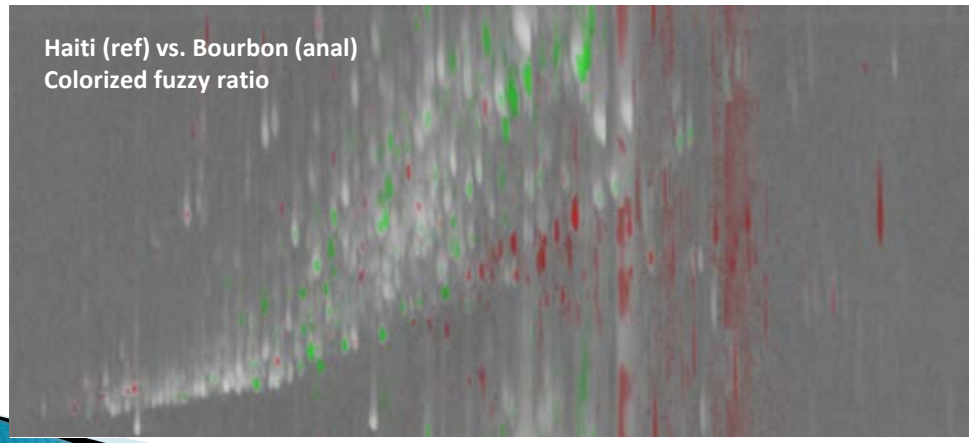
583 or *Brazil*
540 for *Java*
553 for *Haiti*
733 for *Bourbon*

J.-J. Filippi et al. / J. Chromatogr. A *1288 (2013) 127– 148*

Real-world samples

Chrysopogon zizanioides L. (vetiver) EOs
Comparison Haiti vs. Bourbon type





Templates of un-targeted peaks
EO "type" chemical signature

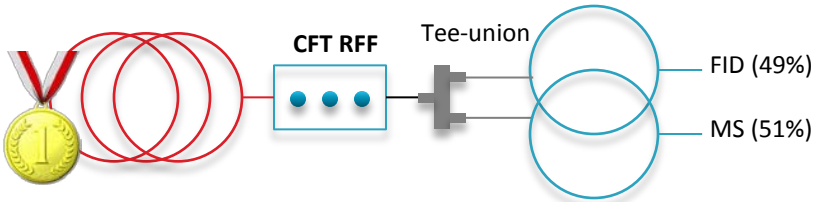
Fingerprinting approaches
Visual features
Peak-region features

Image comparison
Pseudocolor comparisons
Colorized fuzzy ratio
Red-green regions reveal compositional differences

Real-world samples

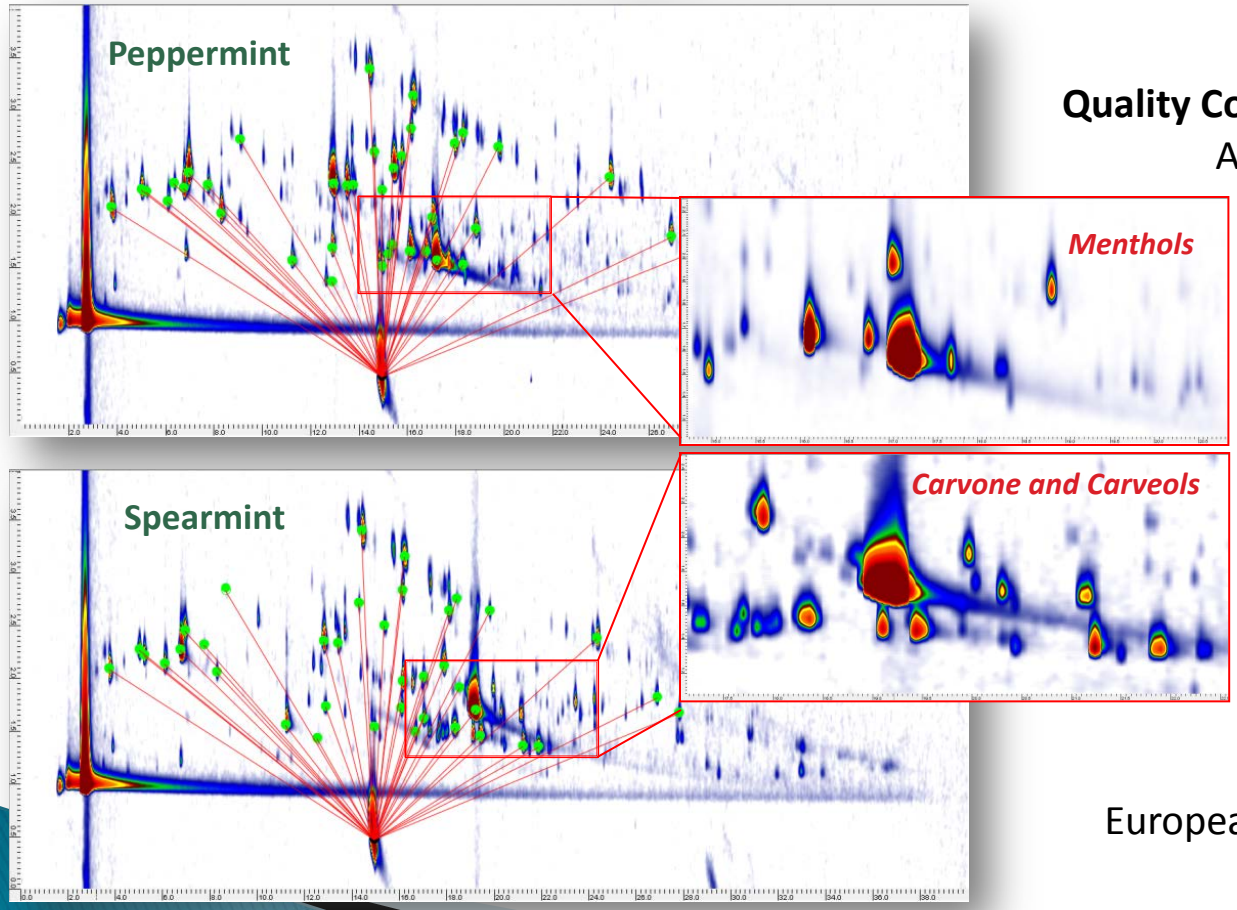
Mentha x *piperita* L. (peppermint)
Mentha spicata L. (spearmint)

V. Polar - Medium Polarity PEG-OV1701



^{1}D - Polar PEG
10m×0.10mm×0.10µm
He carrier @ **0.40 mL/min**

^{2}D - Medium Polarity OV1701
two parallel 1.5m×0.10mm×0.10µm
He carrier @ **4 mL/min**



Mint spp. EO Alt. Conf. PMp4 (PEG-OV1701) - Oven 50°C(1') to 260°C(10') @ 5°C/min Modulation period: 4 s - Injection: 0.11 s - Analysis time 44 min

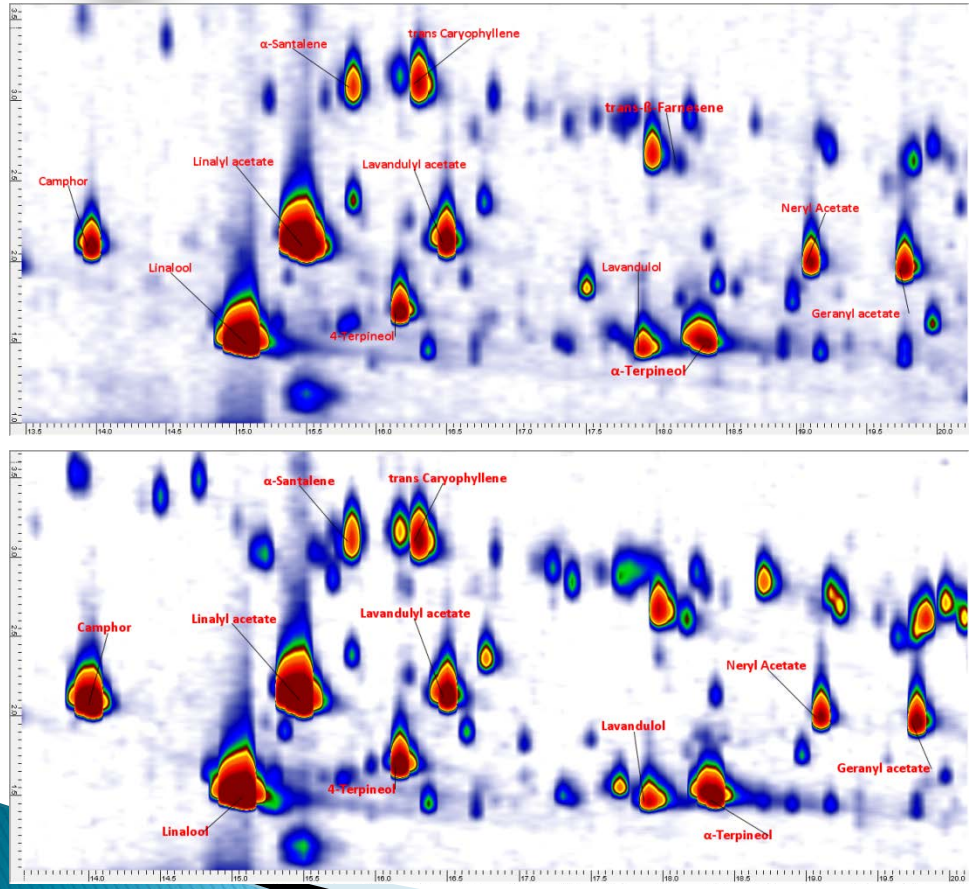
Quality Control & Authenticity assessment
Area Percentage (Area %) intervals
Ratios between markers

- ✓limonene
- ✓1,8-cineole
- ✓ menthone
- ✓ menthofuran
- ✓ isomenthone
- ✓menthyl acetate
- ✓isopulegol
- ✓menthol
- ✓pulegone

European Pharmacopoeia [VIII ed. 2014]
United States Pharmacopeia
ISO References

Real-world samples

Lavandula angustifolia Mill. (lavender)



Lavender spp. EO Alt. Conf. PMp4 (PEG-OV1701) - Oven 50°C(1') to 260°C(10') @ 5°C/min Modulation period: 4 s - Injection: 0.11 s - Analysis time 44 min

Quality Control of lavender EOs

Area Percentage (Area %) intervals
Ratios between markers

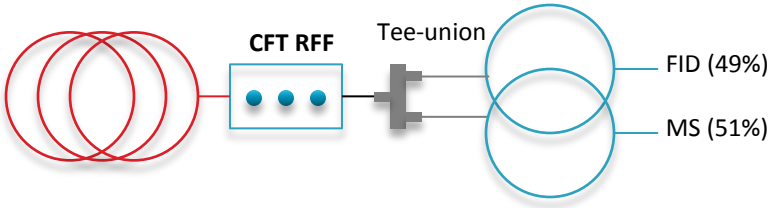
- ✓linalool
- ✓linalyl acetate
- ✓lavandulyl acetate
- ✓4-terpineol
- ✓lavandulol
- ✓1,8-cineole
- ✓camphor
- ✓borneol

European Pharmacopoeia [VIII ed. 2014]
ISO References

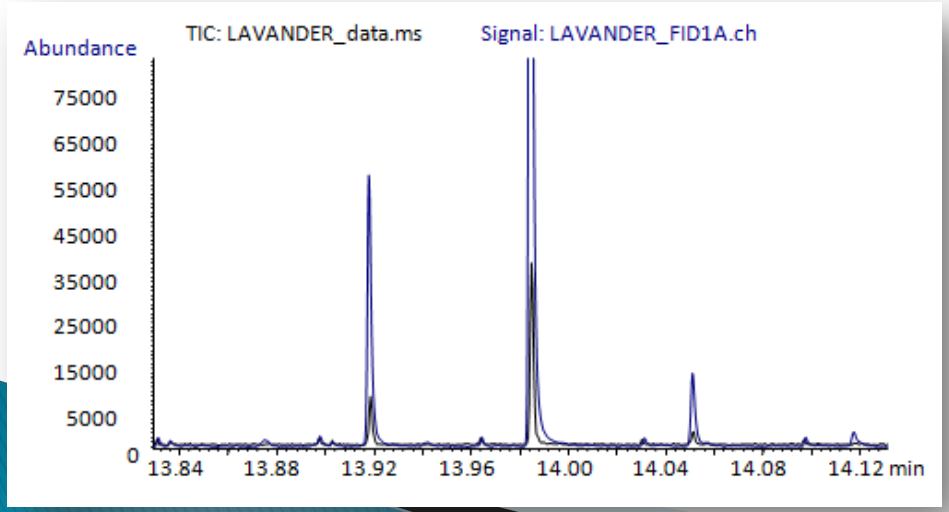
Suspected allergens (restrictions)

Real-world samples

Regulated substances
according with Quality Standards for Product Conformity Assessment
MS confirmatory methods are mandatory
(Commission Decision EC 657/2002)



The system operating with parallel separation/detection enables to:
✓Identify / confirm ID by EI-MS spectrum
✓Quantify by FID (external calibration and Response Factors) and by MS

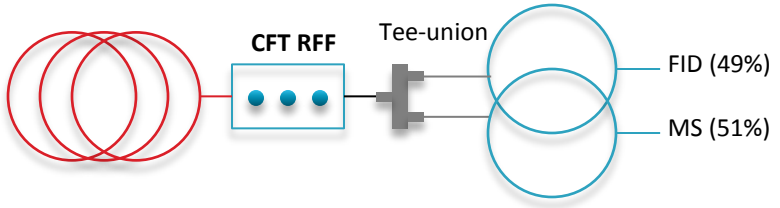


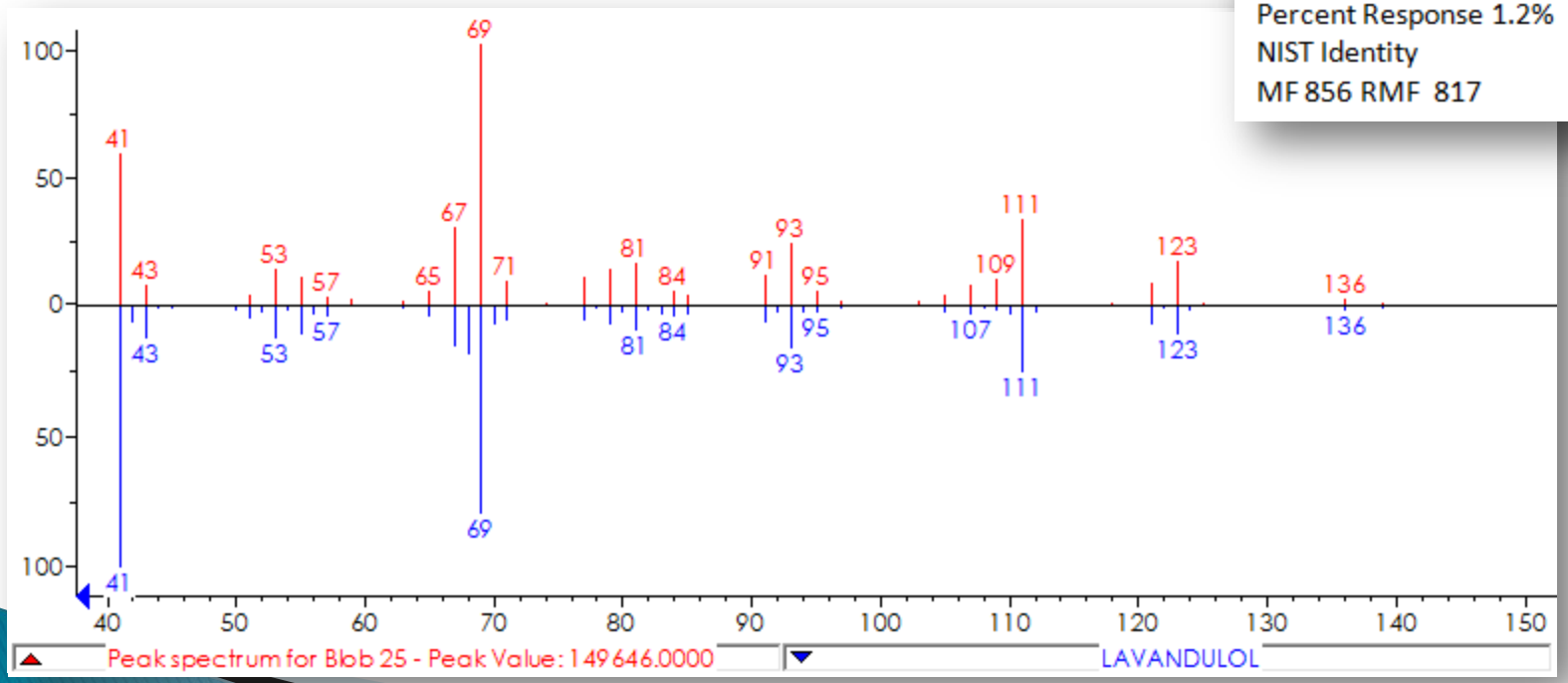
Alignment of FID-TIC MS signals
raw data chromatograms
Target analyte: camphor

MS data (Signal m/z 95)
Pk-pk S/N Corrected signal/Pk-pk noise 258
FID Signal
Pk-pk S/N = Corrected signal/Pk-pk noise 304

Real-world samples

Regulated substances
according with Quality Standards for Product Conformity Assessment
MS confirmatory methods are mandatory
(Commission Decision EC 657/2002)





Conclusions

Le.04

A CRITICAL ASSESSMENT OF THE CURRENT STATUS AND POTENTIAL FUTURE OF GC×GC

Matthew Klee[1], Leonid Blumberg[2]

11th GC×GC Symposium
Riva del Garda, Italy

DSTF

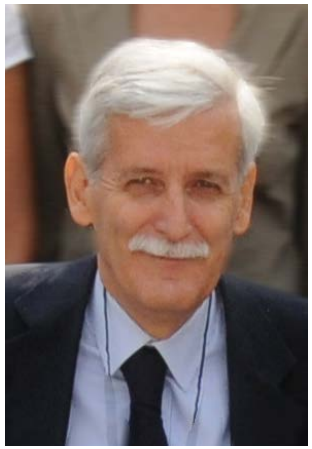
....

- *Differential flow modulated GC×GC with reverse fill/flush dynamics is a promising approach to popularize MD methods in F&F*
- *The system has shown to provide reliable and satisfactory results in profiling and fingerprinting medium-to-high complexity EOs*
- *The system has acceptable operational costs*
  Relative ease of use and simple maintenance

But…

- *Issue to overcome data elaboration and interpretation require a change of mind compared to conventional 1D-GC*
  Chromatographers (old and young) are very conservative

Thank you for your attention



Prof. Dr. Carlo Bicchi

Prof. Dr. Patrizia Rubiolo

Dr. Cecilia Cagliero

Dr. Barbara Sgorbini

Dr. Erica Liberto

Dipartimento di Scienza e Tecnologia del Farmaco
Università di Torino, Turin, Italy

Acknowledgments

Agilent Technologies - USA
Roger Firor & Matthew Giardina

Agilent Technologies - Italy
Armando Miliazza

SRA Instruments - Italy
Luigi Cobelli & Gianluca Stani

GC-Image
Steve Reichenbach & Qingping Tao