

ALEXYS Analyzer  
for Highest Sensitivity  
in Neurotransmitter  
Analysis

**Monoamines and  
Metabolites**

Noradrenaline  
Dopamine  
Serotonin  
5-hydroxyindole acetic-  
acid (5-HIAA)  
3,4-dihydroxyphenylacetic-  
acid (DOPAC)  
homovanillic acid (HVA)

**OPA derivatized amines  
and amino acids**

GABA and Glutamate  
Histamine (LNAA)  
4-aminobutyrate (GABA)  
Glutamate (Glu)  
LNAA

**Choline and  
Acetylcholine**

Choline (Ch)  
Acetylcholine (ACh)

**Markers for  
oxidative stress**

3-nitro-L-Tyrosine  
8-OH-DPAT

**Glutathione and  
other thiols**

# ALEXYS Neurotransmitter Analyzer for On-line Microdialysis Sampling

- **Immediate feedback on the microdialysis experiment**
- **Multi component analysis in parallel UHPLC**
- **High time resolution**
- **High throughput, up to 4 simultaneous experiments**

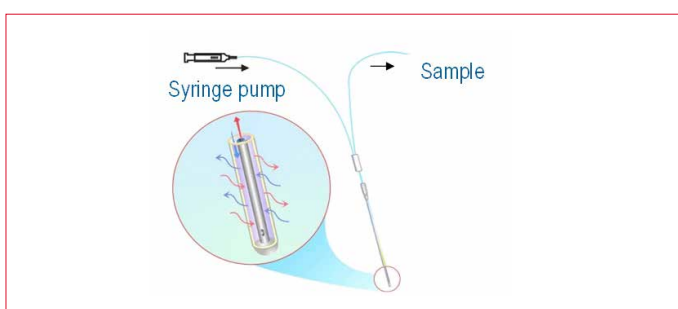
## Summary

The ALEXYS Neurotransmitter Analyzer is a modular system for UHPLC with electrochemical detection of neurotransmitters. This application note shows the applicability of the system to measure various biogenic amines in on-line microdialysis (OMD) which is a continuously flowing microdialysis sampling setup. Instead of collecting samples and putting them in an autosampler, the sample is collected in a sample loop and injected into the system for immediate analysis. During analysis the next sample is already being collected in the loop and the process repeats continuously. Different set-ups are highlighted for improved time resolution, high throughput, and a parallel setup for multicomponent analysis (biogenic amines and metabolites).



## Introduction

Microdialysis is a well-established technique for selectively sampling specific components from living tissue. In-vivo microdialysis is applied to analyze neurotransmitters in specific brain regions [1-4]. The principle is based on a semi-permeable probe being inserted in tissue, and continuously perfused with artificial cerebrospinal fluid (aCSF). Small molecules that pass through the dialysis membrane enter the perfusion fluid which is collected for further analysis (Fig. 1). The monoamine neurotransmitters are present in low concentrations, they are analyzed with UHPLC/ECD using the ALEXYS Neurotransmitter Analyzer (Fig. 2).



**Figure 1:** Principle of microdialysis. Perfusion fluid is pumped through a hollow fiber, small molecules pass through the semi-permeable membrane.



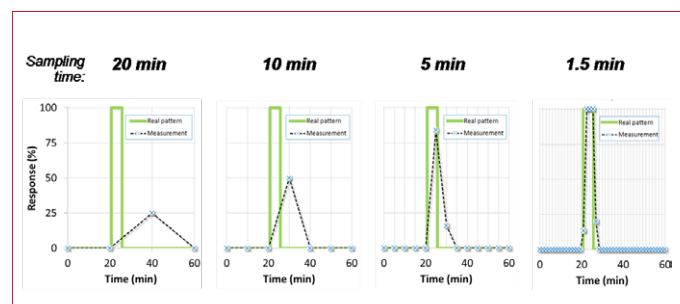
**Figure 2:** ALEXYS Neurotransmitter Analyzer for on-line microdialysis equipped with an electrical valve.

## Several configurations are available

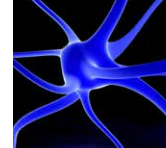
■ *On-line microdialysis* for repeatedly analyzing the microdialysis perfusion liquid. During HPLC analysis, the valve switches back to Load position and the succeeding sample is being collected. Time resolution is the time between subsequent injections and is usually determined by the HPLC analysis time. Data are readily generated, which allows direct evaluation of the course of the experiment.

- *Time resolution.* To monitor a relatively fast change in neurotransmitter levels, the number of data points has to be sufficient to cover the investigated pattern (Fig. 3). Instead of one injection loop, 3 injection loops are filled in series and simultaneously injected and analyzed in 3 parallel HPLC channels. This improves time resolution with a factor 3. To be able to use smaller sample fractions it is even more important to apply a technique with sufficient sensitivity.
- *High throughput.* A single ALEXYS system has the option to run up to 4 identical analyses in parallel, while keeping the same small footprint of a single system. Up to 4 independent in-vivo experiments can be performed at the same time, thus making efficient use of bench space and resources.
- *Two parallel applications* (e.g. for monoamines and metabolites). The option of the ALEXYS system to run two independent analyses in parallel makes it possible to apply for example the analysis of metabolites and the analysis of monoamines to the sample stream. This increases the amount of information that is obtained from each individual experiment.

This note highlights each configuration with data obtained with the ALEXYS Neurotransmitter Analyzer for OMD (Fig. 2). Details on HPLC/ECD settings are in Antec's application notes [4]. The ALEXYS Neurotransmitter Analyzer can also be equipped with an autosampler for off-line analysis of Monoamines, metabolites, GABA and glutamate, or acetylcholine.



**Figure 3:** Increasing time resolution more accurately describes a fast in vivo response (green line).



## Materials and method

### ALEXYS Neurotransmitter Analyzer for on-line LC/EC analysis of monoamines

The ALEXYS Neurotransmitter Analyzer consists of the OR 110 degasser unit with a pulse damper, an LC 110S pump, the DECADE Elite EC detector, and Clarity data acquisition software. For on-line coupling to a microdialysis experiment, additional hardware parts are an electrical injector and the application of specific hardware kits that contain the analytical column and a Sencell flow cell. The analysis of monoamines and acidic metabolites is described in detail elsewhere [3, 4].

### On-line microdialysis hardware

The microdialysis sample stream is connected to a 6 port valve on an electrical injector (Fig. 4). The sample loop has to match the total analysis time and the volume of sample that is generated in that time. As an example, if the total analysis time is 8 min, and the microdialysis flow is set to 2  $\mu\text{L}/\text{min}$ , then the sample size that is available every 8 min is 16  $\mu\text{L}$ . In this set-up, a sample stream is fractionated and analyzed with a single LC/EC method. The time resolution is governed by the time it takes to perform the analysis of a sample.

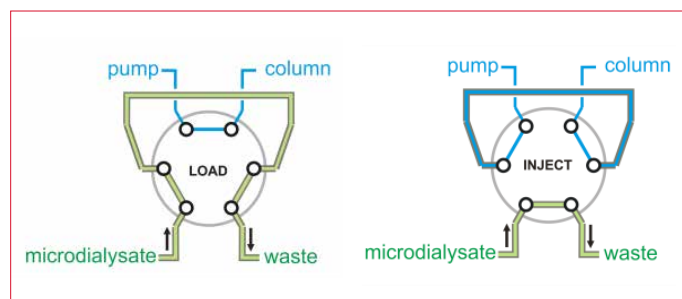


Figure 4: Connections at 2-positions 6-port valve for on-line microdialysis sampling.

### Time resolution hardware

To increase time resolution, the microdialysis tubing is connected to an electrical injector with a 14 port valve (Fig. 5). Instead of one sample loop, the valve is mounted with 3 identical custom fit sample loops connected in series. The sample collected in each of these sample loops gets a unique time stamp in the data plot. During the time of analysis the next sample is being collected. Given the flow rate and analysis time, a loop volume of 5  $\mu\text{L}$  each is chosen.

At every injection, 3 samples will be simultaneously processed in 3 identical parallel running LC/EC flow paths. For

this, a special DECADE Elite with 3 cell controls ('TCC') is used. Three identical analytical columns and flow cells are necessary, but only one pump will suffice when using a flow splitter.

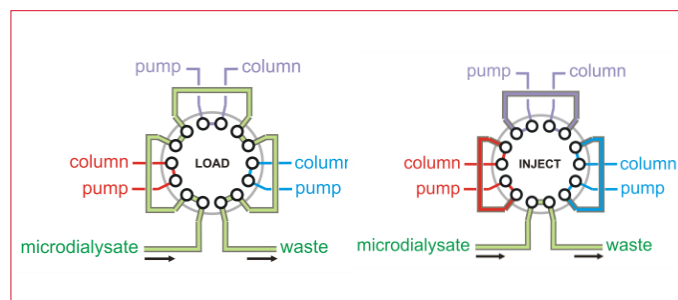


Figure 5: Connections at 2-positions 14-port valve for high time resolution with on-line microdialysis sampling.

### High throughput hardware

In case several identical in-vivo experiments are done with the same LC/EC analysis, the ALEXYS system can be equipped with multiple parallel channels to handle up to 4 on-line set-ups, while maintaining a small footprint. For this set-up, each microdialysis path is connected to an electrical injector with a 6 port valve with one sampling loop (Fig. 4). Each sample loop is connected to an LC/EC flow path containing identical columns and flow cells. At every injection, the samples are processed simultaneously. A special DECADE Elite with multi-cell control has to be used: up to 4 flow cells can be handled with the QCC version, but this detector is also available in versions that handle 3 (TCC) or 2 (DCC) flow cells. One pump with a flow splitter is applied.

### Dual channel applications for the same sample

The microdialysis flow path is split in two equal streams and collected in two sample loops that are connected to an electrical injector with a 14 port valve (Fig. 6). Both samples are analyzed with two different parallel LC/EC channels. For example, the analysis of acidic metabolites can be combined with the sensitive analysis of monoamines, thus increasing the amount of data measured in each sample. For this to work, two independent LC/EC flow paths have to be set up in the ALEXYS system. This means equipping the system with 2 sets of pulse dampers, pumps, columns, flow cells, and a single DECADE Elite with Dual Cell Control (DCC) option. In this set-up, the time resolution is governed by the time it takes to finish both analyses. Also here, the total volume of the two sample loops should match the volume of sample that is collected between every injection.

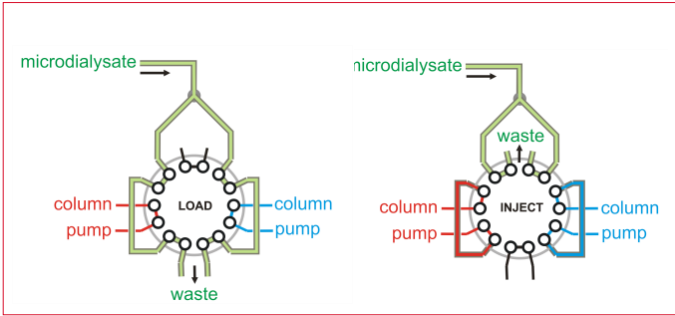
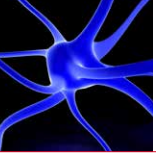


Figure 6: Connections at 2-positions 14-port valve for running 2 independent parallel analyses using on-line microdialysis sampling.

### Calibration

To calibrate a system, a standard with known concentration has to be analyzed. In the on-line microdialysis set-up there are three ways to do this, each with its merits and limitations:

■ **Backwards aspiration - complete loop filling.** Disconnect the microdialysis tubing from the valve and connect a piece of tubing with a plastic syringe attached to the end (Fig. 7). Instead of connecting/disconnecting regularly and creating wear/tear, a manual micro switch like the CMA 110 Liquid Switch is advised. By pulling the plastic syringe, the liquid will move in reversed direction through the sampling loops. The outlet line must be used to aspirate calibration standards. It has to be taken into consideration that the efficiency of filling the loops is 100% in this way, which may not be the case when running the microdialysis set-up. The efficiency of loop filling during an experiment can be measured by comparing the response of a standard that is inserted in the loops by the backward aspiration method, and the response to the same standard, after inserting it in the glass syringe and inserting it automatically into the sample loops under the same conditions of microdialysis sampling. For any combination of microdialysis flow rate and time between injections, loop filling efficiency will be a fixed value throughout the experiment. Note that high loop filling efficiency is important to have enough sensitivity.

■ **Insertion by syringe pump.** Disconnect the microdialysis probe from the tubing and fill the syringe with the standard solution instead of perfusion fluid (Fig. 8). Set the flow rate at the same value as used for the experiment with probe, and repeat 3 or 4 analyses until signals are reproducible. This way of injecting takes into account the efficiency of the loop filling, but it takes more time compared to the backwards aspiration method as it is also necessary to flush and clean the lines and syringe afterwards to prevent carry-over.

■ **Probing.** In this set-up the glass syringe is filled with perfusion fluid, a probe is connected to the flow path and its tip immersed in a standard solution (Fig. 9). The measured responses in a stabilized microdialysis set-up give values that take into account the loop filling efficiency as well as the probe efficiency. Actual probe efficiency can be calculated when comparing with the values as obtained from the insertion by syringe pump method (see Fig. 10 for an example).

It may be clear that all these methods result in values that characterize the system. For daily calibration however, the easiest and quickest method to apply is the backwards aspiration method. Loop filling efficiency is a fixed parameter for a specific set of microdialysis flow rate, loop size and analysis time, so this can also be taken into account as a correction factor for quantifications once it is measured.

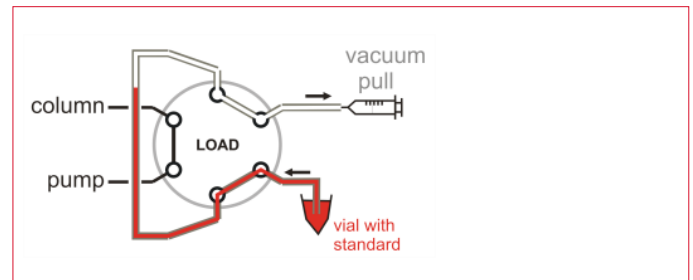


Figure 7: Schematic representation of 'backward aspiration' injection method on a sampling valve.

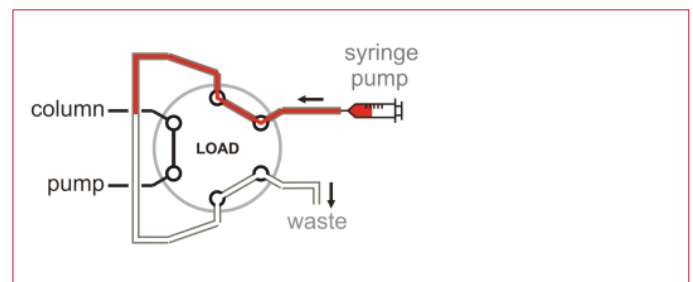


Figure 8: Schematic representation of 'insertion by syringe pump' injection method on a sampling valve

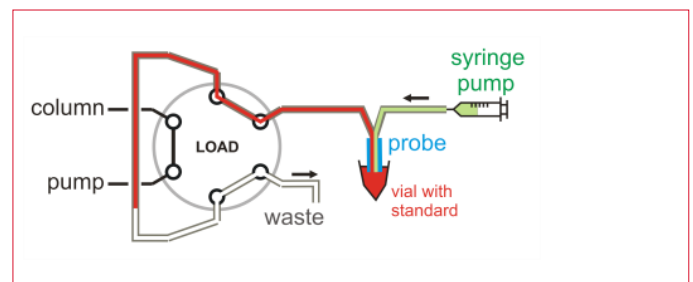
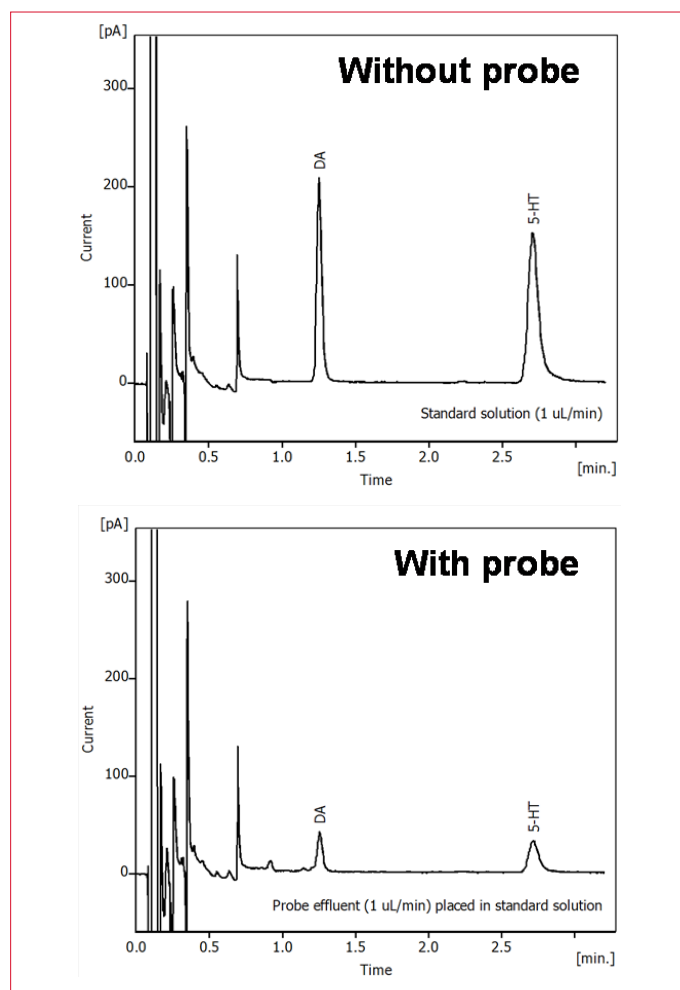


Figure 9: Schematic representation of 'probing' method in an on-line microdialysis set-up.



**Figure 10:** Two example chromatograms used for calculation of probe efficiency. A standard is directly analyzed or sampled through a probe in an on-line microdialysis coupled ALEXYS system. Probe efficiency was calculated to be 15-20% in this case.

## Results and discussion

### On-line microdialysis

Direct coupling of microdialysis with the ALEXYS Neurotransmitter Analyzer results in immediate feedback of the microdialysis experiment. Parameters that need to be coordinated for on-line microdialysis, that differ from a standard off-line approach using an autosampler, are the sample loop size and microdialysis flow rate. The total analysis time and microdialysis flow rate define the total available sample volume for each analysis. This volume has to be collected in the sample loop and injected on column. It has to be taken into account that the loadability of a column can be a limiting factor when analysis times are long. To decrease the sample size in such case, the microdialysis flow rate can be adjusted to a lower flow rate. This will increase probe efficiency (dialysis recovery) as a side effect.

If the total analysis time is for example 8 min for a certain application, the total available sample volume will be 16  $\mu\text{L}$  with the combination of 2  $\mu\text{L}/\text{min}$  microdialysis flow rate. For a microbore column, this is a rather large volume. If the microdialysis flow rate is decreased down to for example 0.8  $\mu\text{L}/\text{min}$ , then the sample volume is almost 5  $\mu\text{L}$  which is more compatible with microbore HPLC.

For applications running under high pressures that require stainless steel sample loops, the available pre-cut volumes are 1  $\mu\text{L}$ , 1.5  $\mu\text{L}$ , 2  $\mu\text{L}$ , 5  $\mu\text{L}$  and 10  $\mu\text{L}$ . The applications that run under pressures where PEEK tubing can be used, sample loops can be made with a tubing cutter. The minimum length of tubing necessary for a sample loop is 10 cm, which corresponds with 1.2  $\mu\text{L}$  when using tubing with an ID of 125  $\mu\text{m}$ . In all cases it is advisable to calibrate the loop volume: tolerances of the materials affect the effective loop volume.

### Time resolution

To show the applicability of the high Time Resolution version of the ALEXYS system, an artificial on-line coupled sample stream with fast changes in neurotransmitter levels was generated for testing. Sample loop filling efficiency was measured for every loop, and the system was calibrated with standards. The example data shown in Fig. 11 were generated with a 9 min analysis of DA and 5-HT, sample loops of 3  $\mu\text{L}$  each and a microdialysis flow rate of 1  $\mu\text{L}/\text{min}$ . Applying analyses with shorter total analysis times will of course result in even higher time resolutions. In principle, time resolution is the analysis time divided by 3 with this set-up.

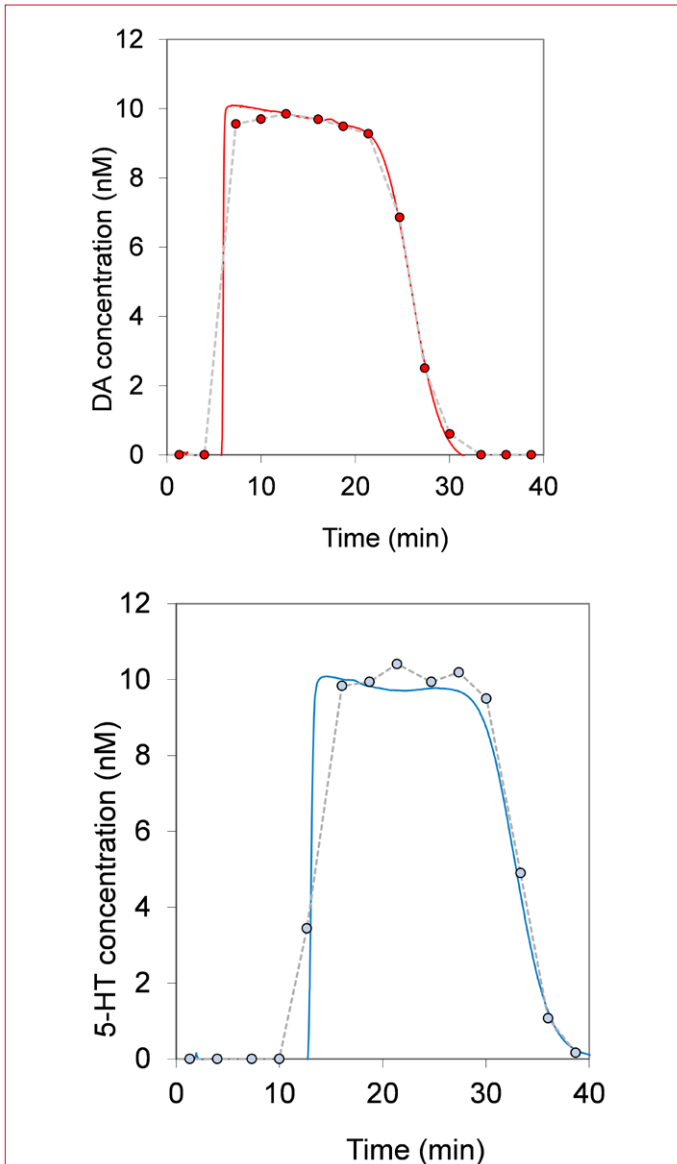


Figure 11: Fast changes in DA and 5-HT levels (red and blue colored profiles) are accurately measured with the ALEXYS Neurotransmitters Analyzer with High Time resolution option (dots and dashes).

### High throughput

The example data for the high throughput version of the ALEXYS system is shown with the analysis of dopamine (Fig. 12). These data were recorded simultaneously from three individual on-line coupled microdialysis experiments using only one ALEXYS system.

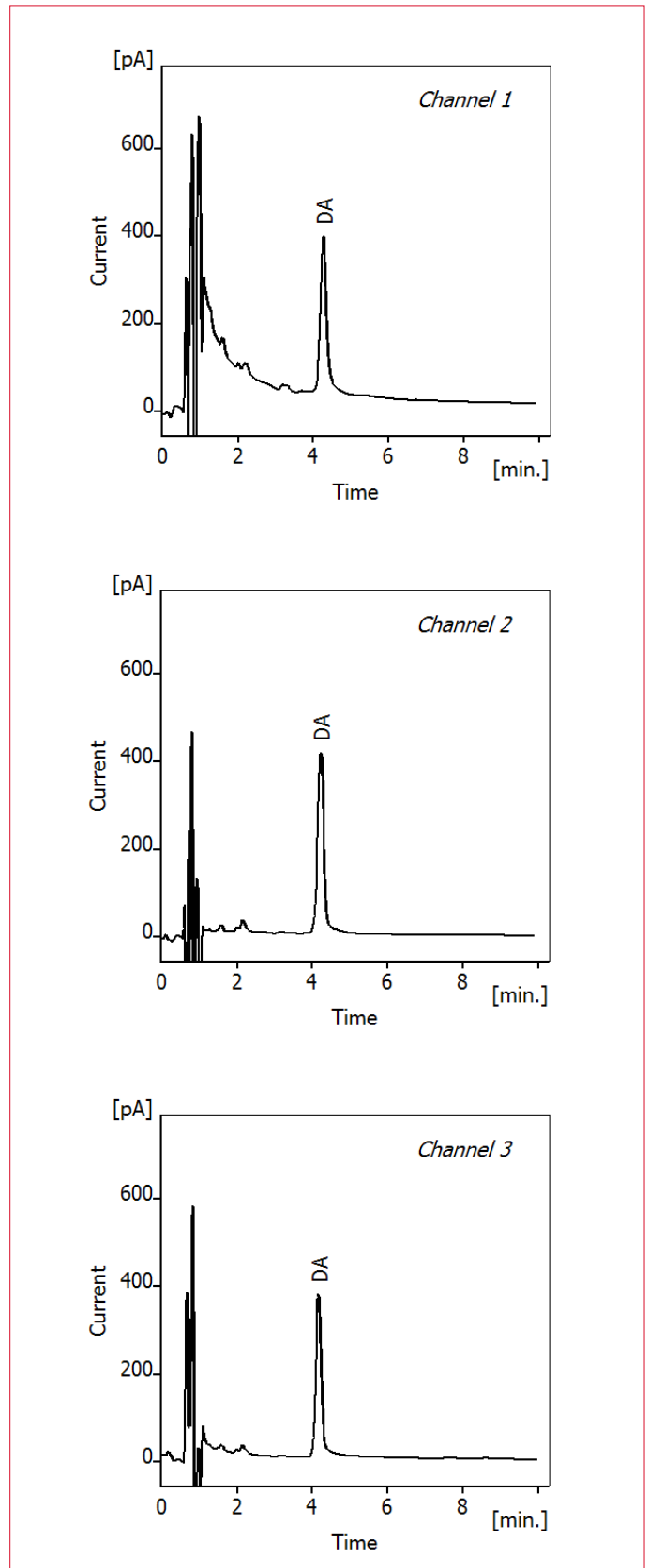
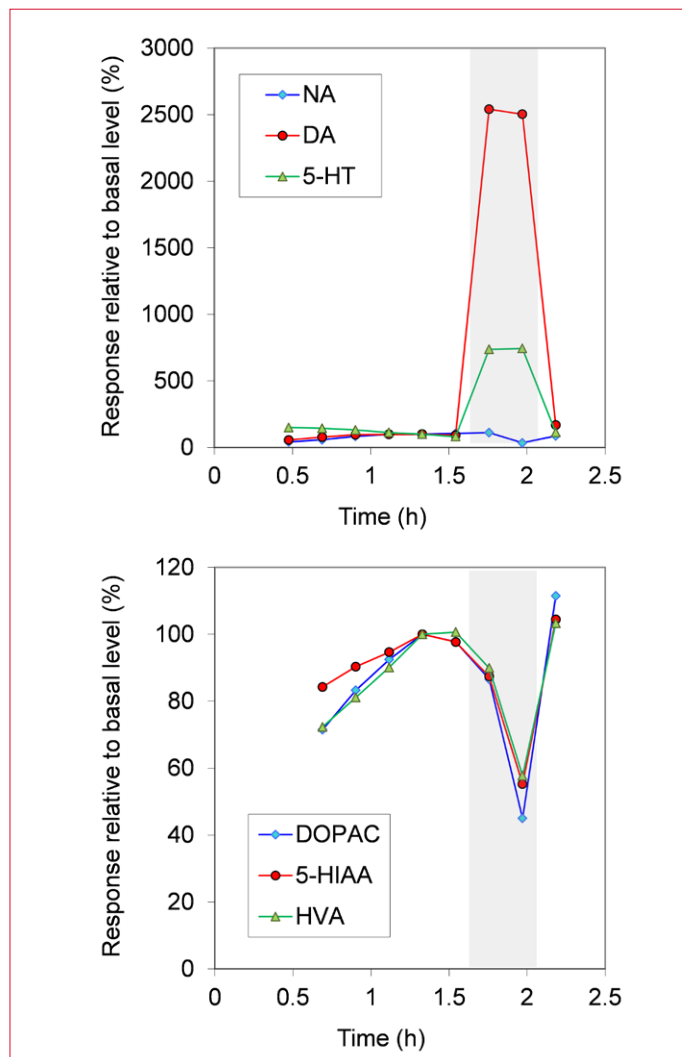


Figure 12: Chromatograms of 10 nmol/L DA in Ringer solution recorded simultaneously for 3 parallel running on-line coupled microdialysis experiments using the ALEXYS Neurotransmitters Analyzer with High Throughput option. Sample loops of 5  $\mu$ L were used for each channel, and perfusion fluid was collected at 1  $\mu$ L/min.



## Two parallel applications

The example data in Fig. 13 shows results from a real experiment with an in-vivo brain microdialysis experiment on-line coupled to the ALEXYS system. The two analyses that were applied to the sample stream were the analysis of acidic metabolites and the analysis of monoamines.



**Figure 13:** Response plots as obtained from an on-line coupled in-vivo brain microdialysis experiment. A sample split set-up was applied for parallel analyses with the ALEXYS Neurotransmitter Analyzer (applications for monoamines and acidic metabolites). The grey area in the graph indicates the time span when the perfusion fluid contained a high potassium concentration to induce a response.

## References

1. Emerging trends in in vivo neurochemical monitoring by microdialysis. Robert T Kennedy. *Current Opinion in Chemical Biology* 2015, 17:860-867
2. In vivo monitoring of serotonin in the striatum of freely moving rats with one minute temporal resolution by online microdialysis-capillary high-performance liquid chromatography at elevated temperature and pressure. Zhang J, Jaquins-Gerstl A, Nesbitt KM, Rutan SC, Michael AC, Weber SG; *Anal Chem.* 2013 Oct 15, 85(20):9889-97
3. Analysis of Glutamate, GABA, Noradrenaline, Dopamine, Serotonin and Metabolites using microbore UHPLC with Electrochemical Detection, Reinhold NJ, Brouwer HJ, van Heerwaarden LM, Korte-Bouws GA.; *ACS Chem Neurosci.* 2013, 4:888–894
4. Antec application notes: Monoamines and Metabolites (213\_028), GABA and Glutamate, Histamine, Amino Acids (213\_020); Acetylcholine and Choline (213\_023).
5. Physiologically relevant changes in serotonin resolved by fast microdialysis. Yang H, Thompson AB, McIntosh BJ, Altieri SC; *ACS Chem Neurosci.* 2013, 4: 790–798

## Conclusion

The on-line coupling of a brain microdialysis experiment to the ALEXYS system is shown to generate data with different features depending on the version of set-up. The simple set-up will give direct feedback of the course of the experiment; the high-throughput set-up can efficiently process 3 or 4 experiments at the same time; the high time resolution version generates data with a 3 x higher time resolution compared to the simple set-up, and the dual application set-up can simultaneously apply two different analyses on the same sample stream.



# ALEXYS Neurotransmitter Analyzer for On-line Microdialysis Sampling

6. Ser129 phosphorylation of endogenous  $\alpha$ -synuclein induced by overexpression of polo-like kinases 2 and 3 in nigral dopamine neurons is not detrimental to their survival and function. Buck K, Landeck N, Ulusoy A, Majbour NK, El-Agnaf OMA, Kirik D; *Neurobiology of Disease*, 2015, 78: 100-114
7. Presynaptic dopaminergic compartment determines the susceptibility to L-DOPA-induced dyskinesia in rats. Ulusoy A, Sahin G, Kirik D; *Proc Natl Acad Sci USA* 2010, 107: 13159–13164.
8. Characterization of cognitive deficits in rats overexpressing human alpha-synuclein in the ventral tegmental area and medial septum using recombinant adeno-associated viral vectors. Hall H, Jewett M, Landeck N, Nilsson N, Schagerlöf U, Leanza G, Kirik D; *PLoS ONE* 8(5): e64844. doi:10.1371/journal.pone.0064844
9. Local salsolinol modulates dopamine extracellular levels from rat nucleus accumbens: Shell/core differences, Lucía Hipólito, María José Sánchez-Catalán, Luis Granero, Ana Polache; *Neurochemistry International*, Volume 55, Issue 4, September 2009, Pages 187–192



ALEXYS Neurotransmitter Analyzer for high throughput. Three valves and one pump with a flow splitter are used for three HPLC channels running in parallel.



ALEXYS Neurotransmitter Analyzer for dual channel analysis of the same sample. Requires 2 pumps for the two independent analyses running in parallel.

## Ordering information

180.0083W	ALEXYS OMD Time Resolution
250.1136	NeuroSep 105, 50 x 1 mm, 3 $\mu$ m, C18-3
250.1504	Column guard holder 1 mm
250.1524	Neurosep guard kit - 1 holder, 2 cart.1 mm ID

180.0082W	ALEXYS OMD High Throughput
250.1136	NeuroSep 105, 50 x 1 mm, 3 $\mu$ m, C18-3
250.1504	Column guard holder 1 mm
250.1524	Neurosep guard kit - 1 holder, 2 cart.1 mm ID

180.0081W	ALEXYS OMD Monoamines Analyzer
250.1110	ALF-105 column, 50 x 1 mm, 3 $\mu$ m C18
250.1114	ALF-115 column, 150 x 1 mm, 3 $\mu$ m C18
250.1504	Column guard holder 1 mm
250.1520	ALF 3 $\mu$ m drop-in cartridge 10 x 1 mm,4pcs

Ask us for alternatives in case you need to analyze a different set of components.

*For research purpose only.* The information shown in this communication is solely to demonstrate the applicability of the ALEXYS system. The actual performance may be affected by factors beyond Antec's control. Specifications mentioned in this application note are subject to change without further notice.

Antec Scientific (USA)  
info@AntecScientific.com  
www.AntecScientific.com  
T 888 572 0012

Antec Scientific (worldwide)  
info@AntecScientific.com  
www.AntecScientific.com  
T +31 71 5813333

