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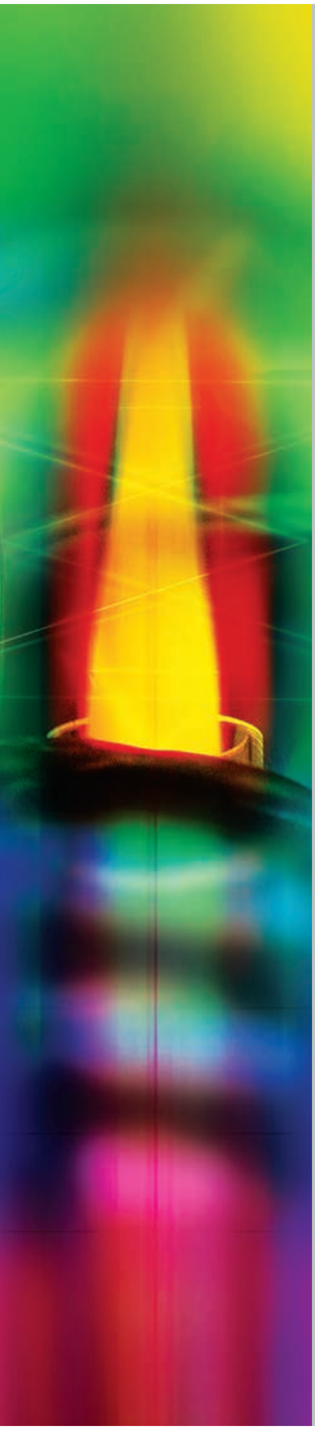
A WHITE PAPER BY
SPECTRO ANALYTICAL INSTRUMENTS



Ten Reasons You Need a Next-Generation ICP-OES for Routine Analyses

Introduction

The elemental analytical needs of many users are best met by a midrange analyzer utilizing *inductively coupled plasma optical emission spectrometry (ICP-OES)* technology. This instrument should be capable of reliable performance — often defined by set standards or government regulations — in a wide range of applications. These include environmental and agronomy, consumer product safety, pharmaceutical, chemical/petrochemical, and food.

A number of spectrometer makers offer products designed to perform routine analyses for this mainstream market. However, not all analyzers are created equal.

Many conventional spectrometers available today suffer from inherent design weaknesses that lead to significant shortfalls in performance. Fortunately, next-generation solutions do exist.

A newer class of midrange instruments — best exemplified by the SPECTROGREEN ICP-OES analyzer from SPECTRO — can deliver superior performance for the applications above, and more. That includes analyses ranging from trace elements in challenging matrices such as certain wastewaters, soils, and sludges; to organic, high-salts and metal samples; to higher concentrations.

This paper outlines ten benefits this kind of improved ICP-OES technology can deliver. Its advantages include smaller footprint; trouble-free cooling; greater power; no gas purging; superior optics; full gas control; next-generation detectors; no-hassle dual-view; reduced matrix effects; and more. Users looking to upgrade their performance should consider this kind of versatile, technologically advanced solution for all their routine analyses.

1. Smaller footprint

Many laboratories aren't spacious to begin with. But as work requirements change, most labs add more and more equipment. Benchtops become extremely crowded — and workflows suffer. So instrument size and footprint can become important factors in evaluating new analyzers.

Unfortunately, the designs of many traditional midrange ICP-OES analyzers don't fully address these needs. While their cabinets may be relatively small, they tend to take up the full depth of a standard lab bench. And all these instruments demand additional space for a monitor setup, an autosampler, and a cumbersome external chiller that often can only be accommodated under the table. For example, one leading model requires a footprint for its entire system totaling 63.5 x 27.1 inches (161.5 x 69.0 centimeters).

However, more space-conscious models are available. For instance, one configuration of the SPECTROGREEN ICP-OES analyzer (with a compact autosampler niche, an integrated "floating" monitor, and no need for external refrigeration) fits in a relatively modest 50.7 x 22.6 inch (129 x 57.5 centimeter) space, without additional components underneath the bench. In fact, it possesses the least depth of any ICP-OES available, as well as the smallest system footprint. The space savings are obvious; the workflow advantages can be significant

2. Trouble-free cooling

Since ICP analyzers operate at power levels up to 2000 W, their plasma generation components require cooling for proper operation. Almost all utilize water-cooling via an external water/air-based chiller for this.

With tight laboratory space constraints (see previous section), this often-sizable unit often can only be accommodated under the benchtop. Also unfortunately, it incurs extra costs for purchase plus significant ongoing energy bills. These chillers are also the analytical system elements most likely to break down — at which point, of course, all analyzer operation stops. Besides extra noise and heat in the lab plus costs for repair or replacement, this can add considerable time, trouble, and expense for system downtime.

However, one model avoids all this. SPECTROGREEN is the only midrange ICP-OES on the market that takes a different direction. Its plasma interface, coil, and generator are all completely air-cooled. This innovative yet proven design saves space, as well as costs for purchase, power, and maintenance. Estimated savings for these items: approximately $1190 (€1500) per year. And the unit's high uptime saves even more

3. More power

How a spectrometer handles more challenging samples and/or different sample matrices depends on its generator and that component's agility — its power to react quickly to changing plasma loads, keeping the plasma stable. Traditional midrange designs operate at comparatively low power: 1200 to 1400 watts (W) at 40 megahertz (MHz). This is less than suitable for high or fast-changing loads, and usually requires utilizing a mechanical high-frequency-matching network.

Weak generator performance can mean samples must be prepared at relatively high dilutions to achieve lower levels of total dissolved solids (TDS). Desirably low limits of detection may remain out of reach. Certain applications, for example the analysis of volatile organic solutions, are either impracticable or require expensive accessory equipment.

By contrast, the SPECTROGREEN analyzer's late-model LDMOS 1700 W generator means samples may not need dilution or complicated preparation at all. The high power and agility of the LDMOS system contribute to the instrument's exceptional matrix compatibility, so it can handle varying sample loads in succession with ease, and analyze difficult sample matrices in lower dilutions to lower limits of detection. In addition, its high efficiency reduces running costs and makes external cooling unnecessary. Finally, the SPECTROGREEN system stays cool and trouble-free while delivering fast warm-up (often less than 10 minutes) for maximum productivity.

4. No purging

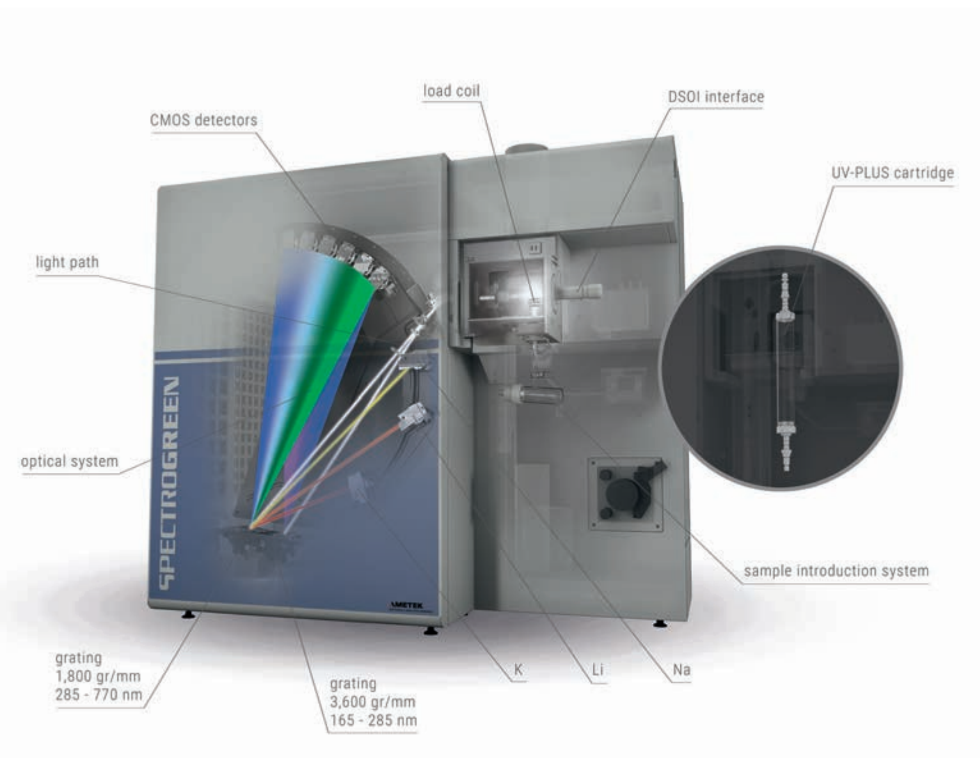
With one exception, every ICP-OES analyzer in this class employs a continuous gas purging arrangement. This must protect the instrument's delicate optical system's light path from atmospheric influences (oxygen and water). These would otherwise rule out measurement in the wavelength range below 190 nm, while also negatively influencing optical components.

Even on standby, such systems require about 1 liter (L) of expensive argon gas per minute — rising to 3-6 L per minute during operation, depending on the analytical application. In addition to its expense, this method also carries the danger of contamination from any of the multiple gas bottles or tanks used over the instrument's lifespan. A single incident that contaminates the optical surfaces will require a troublesome, time-consuming, extensive — and expensive — repair.

Fortunately, one analyzer — SPECTROGREEN — eliminates purging altogether. Its innovative no-purge UV-PLUS technology employs a small purifying cartridge (lifespan: 2 years) in an argon-filled, hermetically sealed system. So users minimize the chance of contamination. And the savings on wasted purge gas consumables amount to approximately $3500 (€3000) every year.

5. Better optics

Almost all ICP-OES analyzers still use the same type of traditional optical system, with similar features and legacy echelle-type designs. But in some analytical situations, these systems fall short of delivering satisfactory results.



For example, they utilize four to eight internal reflective/transmission components (mirrors, prisms, cross dispersers, etc.). But light throughput decreases by up to 15% at each reflection. So these systems can lose significant sensitivity, especially for elements in the ultraviolet (UV) below 190 nm.

Since different diffraction orders are not always completely separated, these systems are susceptible to interference. Stray light reflecting from those multiple optical components increases background radiation and further affects sensitivity. This also makes it harder to arrive at lower limits of detection, and to analyze line-rich matrices containing metals or some organics. Additionally, resolution may vary: good in the 200 nm range, but worse above 300 nm. Line-rich metal matrices become even more challenging, and may require extra processing — plus more time, trouble, and expense — to achieve even minimal accuracy.

Their relatively large optical system volume requires expensive gas purification (see previous section). Their open optics lead to variable pressure, degrading wavelength measurement stability. And their cooled detection system may trigger failures caused by condensing and/or freezing humidity on detector components. All this may necessitate continual, troublesome adjustments or costly repairs.

To avoid these problems, SPECTRO ICP-OES analyzers such as SPECTROGREEN utilize unique yet proven optics based on Optimized Rowland Circle Alignment (ORCA) technology.

This high-performance system utilizes only three optical surfaces (slit, grating, and detector) to maximize light throughput. So its more direct light path can achieve superior sensitivity for the ultraviolet / vacuum ultraviolet (UV/VUV) region, including elements such as aluminum (Al), lead (Pb), phosphorus (P), sulfur (S), tin (Sn), arsenic (As), and mercury (Hg).

It achieves high, constant resolution across a wide spectral wavelength range: avoiding spectral interferences, and improving the accuracy of the user's results. Its low level of stray light provides lower background radiation — allowing lower limits of detection, as well as more trouble-free, accurate analysis of higher matrix samples containing metals or organics.

The analyzer's small-volume, hermetically sealed optical system also provides purge-gas-free purification, and it's thermally stabilized to 89 °F (32 °C). So the user gets high wavelength stability for continued accuracy, with no contamination or condensing/freezing problems. Results: fewer calibrations or control samples, and less need for rework.

6. Total gas control

In an ICP-OES analyzer, stability is critical for accurate measurement. But stability is a product of several system components. As already discussed, these include a powerful generator and a precisely controlled optical system. But they also include exact control of all gas flows, so that conditions in the plasma and within the transfer optic remain stable.

Unfortunately, most ICP-OES models offer only partial and/or low-level solutions for this requirement. Very few provide continuous control of gas flows in the light path. And lower-cost analyzers offer volume or mass flow control only for nebulizer gas; all other flows are governed by simple on/off solenoids.

SPECTROGREEN provides continuous, software-directed, volume control for all gases — to ensure maximized stability for precise measurements. That includes continuously adjustable coolant, auxiliary, nebulizer, and light path flows; a proportional valve gas distribution controller plus an optional, separate controller for oxygen or additional gas; and software displays of flows and pressures.

7. Next-generation detectors

Traditional ICP-OES analyzers are equipped with single two-dimensional (2D) semiconductor detectors. While providing good results for many analytical tasks, a system based on this technology also suffers some critical shortcomings.

One troublesome effect is *blooming*. As on a camera where a bright light washes out its surroundings, a reading of extreme intensity for one element will cause excess charges to migrate to neighboring pixels. So the peak is too broad, the edges are erratic — and an adjacent peak generated by a lower elemental signal gets obscured. One example: mineral water samples with high concentrations of calcium (Ca), which can create intense matrix peaks and "bloom out" adjacent lines.

Another issue set: downtime and cost. If a single 2D detector fails, the entire system is down … and each detector costs approximately $15,000 (€12,600) to replace. Finally, as previously mentioned, these detectors must be cooled to -40 °C (-40 °F), and can suffer measurement failures due to humidity or icing.

However, the design of a next-generation analyzer like SPECTROGREEN replaces 2D detectors with state-of-the-art, low-noise linear array *complementary metal oxide semiconductor (CMOS)* detectors — a proven integrated circuit technology now perfected for spectrometer use. They provide outstanding behavior at extreme light intensities. So there's absolutely no blooming; accurate determination of trace concentrations even when adjacent to intense matrix peaks; and smooth peak flags. Results: high sensitivity and precision with virtually any matrix or sample composition.

These advantages are combined with fast readout, so full spectrum processing and transfer are performed in minimal time: less than 100 milliseconds (ms). Detectors have a failure rate of less than 0.1% — but even if one line array detector should fail, all others remain operable, without system downtime. And that detector can be replaced for drastically lower cost. Finally, the analyzer's thermally stabilized optics mean a detector requires no on-chip cooling and faces no humidity or icing hazard.

8. No-hassle dual-view

An important difference between ICP-OES designs lies in how a given analyzer's optical interface views the light emitted from its plasma, which it must analyze and measure. An *axial-view* system observes light from end to end down the plasma's whole central channel. A *radial-view* system looks at a slice of light across the plasma width. A dual-view system manages to observe light both axially and radially. Note that when collecting spectral information, usually the more light, the better. So for example, axial views provide inherently higher sensitivity than radial views. But they suffer from several interferences that can degrade measurement.

One popular solution is the *vertical-torch dual-view* system, which takes a primary radial view across the plasma, supplemented by a sequential axial measurement taken down the plasma's central axis. This axial "second look" is supplied via several mirrors, arranged in a periscope optic mounted just above the plasma. While this vertical-torch dual-view approach can avoid axial interferences, it also reduces an axial view's main strength: sensitivity. Additionally, the vertical orientation means contaminants may fall from the interface into the plasma, ruining accurate measurement. Finally, thermal stresses on the interface just above the superhot plasma can inflict significant wear.

One recent technology captures the advantages of vertical-torch dual-view systems without their hassles: the *dual side-on interface (DSOI)* approach available for SPECTROGREEN analyzers. In this design, the radial view is effectively doubled. DSOI uses a high-stability, vertical torch whose plasma is observed via a unique direct-light-path radial-view technology, which, unlike any previous design, deploys two radial optical interfaces.

Since light is transferred into the optical system from two sides instead of one, the instrument's sensitivity is on average improved by a factor of two — comparable to that of vertical-torch dual-view systems, because DSOI features fewer reflective surfaces. In addition, its vertical torch provides high stability and freedom from interfering matrix effects, since troublesome zones in the plasma are blanked out. The results include high stability, high matrix tolerance, high linear dynamic range, and freedom from matrix effects, all with one measurement.

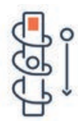
A direct-light-path axial-view instrument such as the SPECTROGREEN TI still exhibits a slight advantage over DSOI in sensitivity. But aside from applications where low detection limits for the alkali/earth elements are needed, the DSOI version of SPECTROGREEN should deliver adequate sensitivity for most routine analyses — trouble-free.

9. Reduced recombination effects

One undesirable phenomenon that can impact axial views is the *recombination* effect. The system's view down the long axis includes cooler region away from the plasma core; here ions, formed in the hot regions of the plasma, recombine — the energy needed for their ionization as well as the access energy the electrons carry are again released, and a continuum-like spectrum is created. The recombination effect strongly impacts the instrument's performance, because the resulting higher background strongly influences its sensitivity. Since axial-view instruments are usually purchased by users with applications requiring the highest possible sensitivity, the effect is especially unwelcome. Various ICP-OES analyzers attempt to deal with this effect in different ways; some are less successful than others.

One of the most innovative and successful solutions is available in the twin-interface version of SPECTROGREEN, whose combined axial/radial plasma view interface offers a direct light path for the axial view. The OPIAir optical plasma interface in SPECTROGREEN TI directs a small argon purge stream through the recombination zone, radially deflecting it away from the light path. Result: the system can achieve desirably lower limits of detection in higher matrix samples such as wastewaters.

10. No matrix glitches



Midrange ICP-OES analyzers sometimes face difficulties in measuring certain samples, as the instrument encounters a number of undesirable effects. (See previous discussion for recombination effects.) For example, matrix interferences include the *easily ionizable element (EIE) effect* that can plague axial-view systems, resulting in incorrect determination of alkaline elements in applications such as environmental testing. This can be corrected by addition to the sample of a highly concentrated ionization buffer, but side effects include increasing the matrix load and possibly adding contamination.

Most serious matrix effects can be avoided by using advanced midrange models such as SPECTROGREEN TI. Again, its proven twin-interface approach automatically combines both axial and radial plasma views, providing the highest sensitivity while eliminating matrix effects. For example, the EIE effect is greatly reduced, since alkali/earth alkali elements in samples such as mineral waters are measured in its radial mode.

There's no need for an ionization buffer, with its risks of contamination. Elements such as toxic heavy metals can still be determined with greatest sensitivity, since — unlike current vertical-torch dual-view models, which offer direct light only for the radial view — the instrument measures these elements in the direct light path of the instrument's axial mode. SPECTROGREEN TI's design also allows dynamic range and linearity to be further expanded. The results: maximum sensitivity for trace elements, as well as freedom from matrix interferences plus good accuracy for challenging environmental and agricultural matrices.

CONCLUSION

In the near future, many users may seek to upgrade their capabilities to perform routine elemental analyses in applications such as environmental and agronomy, consumer product safety, pharmaceutical, chemical / petrochemical, and food. Those evaluating currently available ICP-OES analyzers should be aware of some significant shortfalls in many traditional designs. However, they can find solutions in next-generation analyzers such as SPECTROGREEN, which offers a host of innovative advantages for current and future needs in this mainstream analytical space.

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