Laser focus

Port Equipment Manufacturers Association (PEMA), London, UK

Laser technology was initially deployed in the early 1990s, coinciding with the first major automation initiatives in the container terminal industry. Since then, the drive towards more automated and safer container handling has engendered a productive collaboration between terminal operators and laser technology suppliers, spurring rapid performance improvements and an expanding range of applications.

The workflow in an automated terminal is potentially higher, more consistent and safer than for manned operations – hence the growing industry interest. But in automated facilities, robotic or remotely-controlled handling equipment has to 'see' and position itself to a high degree of accuracy. Also, as unmanned operations do not mean there are no people on the terminal, there is a need for safety devices that can recognise and respond to potentially dangerous situations.

Both of these areas depend heavily on automated recognition. Laser, along with other location and identification technologies like RFID, GPS, OCR and radar, is therefore a key component in today's automated terminals. Manual terminals are also implementing laser systems to improve safety, such as in collision prevention.

Key applications for laser systems today include:

- Verifying the position of trucks, trailers and AGVs under quay cranes
- Preventing collisions between crane booms and vessels
- Creating ship bay profiles to guide spreaders over containers on deck
- Container position detection and automatic container handovers in automated stacking crane (ASC) operations
- Gantry, stack, pathway and cross-travel collision avoidance in RTG operations
- Measuring the position of trucks alongside RTGs
- Positioning and guiding E-RTGs on power bars
- Distance measurements from the trolley or spreader to the load
- Collision avoidance in straddle carrier, automated truck and AGV operations
- Identifying whether twin-twenty spreaders are handling 2x20ft or 1x40ft container before lifting commences
- Avoiding trucks being accidentally lifted during container handling due to locked twistlocks
- Assistance for lift truck and reach stacker drivers
- Container damage detection

Laser technology and types

Depending on the specific application, laser systems in terminals can have a measuring range from mm/cm up to 1km. Various laser types are currently used:

Single dimension (1D) laser: These comprise a laser diode, receiver, optics and a processor with a high resolution clock. In operation, the diode sends a laser impulse while the clock starts counting time. When the laser beam hits the target, some of the light is reflected back. This stops the clock and the time taken at this point is used to calculate the distance between sensor and object. This is the time of flight (ToF) method that underpins all laser measurement.

The frequency of a 1D laser is up to 20,000 measurements a second (m/s). By averaging several measurements, accuracy can be as precise as +/-2 mm. Applications for 1D systems include vessel profiling, trolley and spreader positioning, container distance measurement and crane-to-crane collision prevention.

2D laser: The core of the 2D laser scanner is the same as the 1D. However, the 2D version also has a rotating mirror or glass prism deflection unit. The readings from this unit, which combine distance and angle of deflection, can be used alongside the other data to generate a 2D picture. Typical applications include stack and vessel profiling, truck positioning, various types of collision avoidance, twin-twenty detection and anti-truck lifting.

The field of view that a 2D system can verify depends on the laser scanner type, but typically includes 70°, 190°, 270° or full 360° angle. 2D systems have a measurement range of 10-80m, depending on scanner type, on a deep black target with a remission (reflectivity) of 10%.

In general, 2D scanners can be used for two operation modes:

- Detection with field evaluation cases, which triggers 'simple' switching outputs. For example, this function can be used in collision prevention cases where warning and stopping fields can be freely configured to the individual case
- Ranging, which uses the measurement data of the laser scan to generate a profile of the environment or an object. This type of operation is used in positioning applications or stack profiling for load collision avoidance

Multi-layer 2D laser: These scanners have the same principal function as 2D lasers but in layers ('multi-scan planes') which differ in vertical aperture angles. The core applications today for this system include pathway and cross-travel collision prevention.

3D laser: This system works with two different methods to generate a third dimension: either via a rotating 2D laser scanner or through deflection of the laser beam by a second rotating mirror unit. Applications include vessel and stack profiling, stack collision avoidance, pathway and cross-travel collision prevention, truck positioning and container damage detection.

Choosing the right technology

Four key criteria influence system selection:

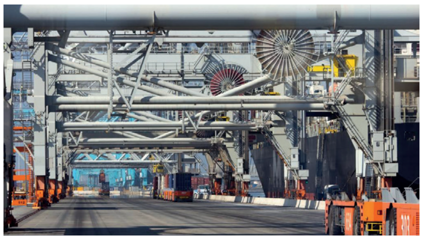
- Distance (range)
- Divergence (spot size)
- Angle resolution
- Accuracy

The maximum distance between a sensor and an object must be assessed. Typical applications in ports need sensors with a range of at least 30 metres, but sometimes up to 80 metres. It must be remembered that the distance a laser can measure depends on the reflectivity of the target (darker targets have lower reflectivity).

The further the distance between the sensor and an object, the bigger the laser spot size. The advantage of a small spot is that small objects can be measured more precisely, for example twistlocks, corner castings or vessel antennae. The beam divergence is measured in mrad = millimetres by metres. This value describes an increase of x mm per metre distance. Typically, outdoor scanners range from 0.7 - 15 mrad.

The angle resolution describes the angle steps of the rotating deflection units. Typical angle steps are 0.0225° - 1° and these steps influence how accurately the shape of the objects can be seen.

The accuracy of the sensor can be



expressed by the measurement of distance and the accuracy of deflection angles. In 3D applications, the speed of the deflection unit and the rotating angle are very important.

Lasers in ports

Ports and terminals present a harsh environment that requires optical sensors and systems-specific solutions capable of dealing with conditions like snow, rain, fog and dust, plus shocks and vibrations.

The impact from weather conditions can be minimised by using a mounted weatherhood to shield the optic lens. In hot climates, a sunroof can significantly reduce the potential for sunlight to heat the sensor above its operating temperature range.

Multi-echo technology also helps filter out the unwanted echoes created when a laser pulse encounters 'disturbing objects' such as rain drops, fog or steam, dust, glass and foil. This ensures reliable object detection even under unfavourable environmental conditions.

Laser system performance

The scan frequency is one of the most important system performance factors as it expresses how often objects can be seen. When objects are in motion, the number of scans has to be high enough to track the movement. The behaviour of the laser when the spots hit part of the edge of the object and part of the background (i.e. the ground) is also significant. This means that system accuracy is partly dependent on the sophistication of the application software running in the processing unit.

Aside from 1D laser distance measurement systems and 2D applications where the laser is used simply for field surveillance operations, all the solutions provided by 2D and 3D laser scanners require intelligent data processing.

This cannot be carried out by crane PLC controls as the data rates of the scanners are too high, and because information needs to be verified during commissioning and maintenance. Therefore an extra controller with application-specific software is required.

The data processing module is a high performance unit enabling fast evaluation of sensor measurement data and for generating results. Typically, it is an industrial PC based on Windows OS. The module should include all software tools to generate the result:

- Communication interface to the laser sensors
- 2D and 3D visualisation of the measurement data
- Status and event message handling
- Algorithm for object capturing and position determination
- Filtering of data (defining what is of 'interest' in the field of view)
- Calibration
- User set-up and maintenance modules
- Interface to a superior PLC system

In conclusion

When using laser technology as part of an automation programme, the details are important. For example, the choice of sensor has to be integrated with the total system, and the role of data processing cannot be underestimated. Ensuring that solutions can be easily managed by the end user is also vital. As these systems rely on complex data from the lasers it can be difficult to interpret the results. Therefore, the industry must give users the tools and methods to easily set up and maintain laser systems. In this regard, it is indeed salutary to note that the effort needed to develop these tools and methods may easily exceed that required for pure application development.

About the organisation

Founded in 2004, PEMA provides a forum and public voice for the global port equipment and technology sectors. The Association has seen strong growth in recent years, and now has over 80 member companies representing all facets of the industry, including crane, equipment and component manufacturers; automation, software and technology providers; consultants and other experts.

This article is based on PEMA's Information Paper "Laser Technology in Ports and Terminals". Developed by PEMA's Technology Committee, the paper provides a practical overview of current applications for laser technology at the quay, yard and gate, as well as in horizontal transport operations. It is the 8th information paper to be published by PEMA and complements existing technology briefings covering RFID, OCR and container yard automation. It is available for free download at http://www.pema.org/publications/.

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