On the safe use of long-range laser active imager in the near-infrared for Homeland Security.

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ABSTRACT

Laser active imager are introducing a new paradigm in the domain of surveillance. Because they provide the capacity to image objects based on their reflectivity and not their emissivity, and because they provide a capacity to see through glass. Moreover, because that being based on high-performance gated intensified tubes, they can operate in adverse atmospheric conditions, and are becoming looked at as a very valuable tool to gather precise identification information at long ranges. On the other hand, the laser source making this technology so interesting must offer a safe operational mode of deployment.

In this paper, we will show the most recent results that this technology can achieve in ship identification and discuss how to implement safety features to make the laser active imager an eye safe new tool for long range observation whatever its wavelength.

Keywords: Active Imager, Range-Gated Imaging, Laser Camera, Laser Illuminator, Near-infrared Imager. Night-Vision, Long Range Identification.

1. INTRODUCTION

There has been a fair numbers of piracy acts declared by the International Maritime Bureau (IMB) for the last years. These incidents usually happen when the target is relatively close to the coast, up to 10 km away. Some happen even as the ship is leaving the dock shortly after being loaded. , Up to now, the best tool available for long range surveillance in support of the task of Homeland Security groups around the world are the radar stations sometimes with the help of day camera and less frequently, of thermal imagers. These technologies are more than efficient at detecting many of the targets, but they are totally ineffective in providing an identification of the threat at long range.

To adequately support the security agencies in their mission against this rapidly growing menace, Obzerv is offering a high definition laser assisted NIR camera called the ATV-2000i. Based on two main core technologies, a range-gated image intensifier and a high rep rate laser diode illuminator, the ATV-2000i is an active imager capable of effectively providing the identification required and unequaled yet with other surveillance technologies.

The thermal imagers cannot see through the glass window of a wheelhouse. Neither can they provide the confirmation of the alpha-numeric registration signs of a boat. Similarly, the most sophisticated image intensifiers cannot provide those information without moon or star light. On the other hand, the active imagers can show a ship's name at more than 7 km in the dead of the night.

However, this does not come free because laser sources have always been considered a dangerous source of illumination and must be configured in a way that there will be no danger to the public.

2. THE THREAT

Following are few of the messages that can be found at the web site of the International Chamber of Commerce – International Maritime Bureau (www.icc-ccs.org). They describe quite well the ever growing problem the society must face in the domain of transportation of goods overseas:

> 13.03.2006 at 0930 LT in position 01:21N - 044:40.32E, off Marka, east coast of Somalia.
> Armed pirates in a boat chased a general cargo ship underway. They fired shots at bridge, lifeboat and superstructure, which caused bullet holes. When boat tried to come alongside master altered course and rammed the boat and boarding was averted.

Bangladesh.
Four incidents have been reported at Chittagong anchorages since 17.02.2006. Ships are advised to take extra precautions.
Iraq declared new piracy hotspot, London, 31 January 2006
Despite the good news IMB warns against any let up of anti-piracy enforcement. According to the report, 10 attacks were reported in 2005 compared to none in 2004. IMB says most of the attacks were perpetrated by opportunists who use extreme violence towards crew and whose main motivation is robbery and financial gain. Attacking from small boats, pirates work quickly, mostly attacking vessels at anchor in the vicinity of Basrah oil terminal and Umm Qasr. In one example, a tanker, at anchor, was boarded by three robbers wielding machine guns. They held the Master and Second Officer at gunpoint and fired a shot that narrowly missed the Master before forcing him to open the ship's safe. In other cases, several crewmembers were seriously assaulted and injured.

As can be seen, the threat is coming from everywhere. In other incidents, the robbers seized the full ship to be used as a platform for more audacious robbery or terrorist action depending who have sponsored the piracy acts.
The Figure 1 shows two maps of Asia and Africa illustrating the numbers of attacks in these waters for the last year. These could all have been an opportunity for terrorist groups to take over the command of one those ships. It is a very serious threat that needs immediate high level of attention.

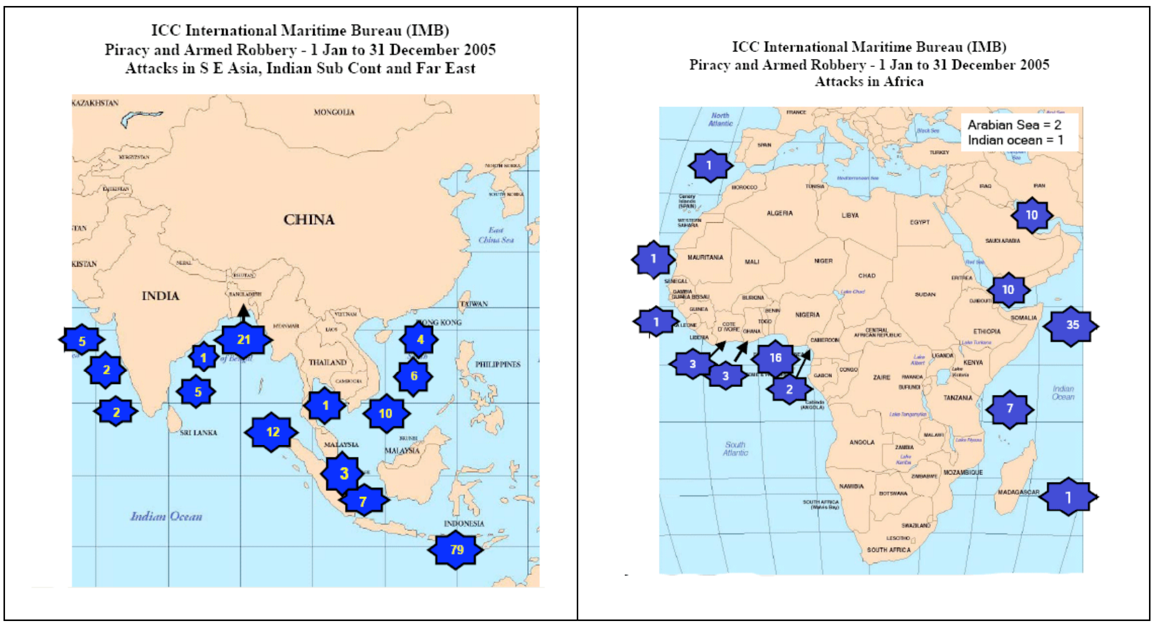

Figure 1: Maps of piracy act between January 1 and December 31, 2005

3. ATV-2000I, AN ACTIVE IMAGER FOR LONG RANGES

4.1. Actual technologies.

To accomplish the surveillance of such large areas, radar station are operating 24/7. In certain installations, they use daylight or intensified cameras and seldom, thermal imagers for classification of the contacts. But for color camera, these technologies cannot provide the type of imagery necessary to accomplish the identification of the ships at long range.
Thermal imagers have been the best tools for detecting and classifying objects at long ranges and they can supplement radars that cannot detect the small targets like the rubber boats or the speed boats as they are the prime tools used by robbers as demonstrated in the precedent section. However, thermal imagers do not have the capability to see through glass, which could be an important step in the process of threat assessment. Also, thermal imaging does not allow the operator to identify by registration marks the name of the ship, and thus confirm the validity of the identification sent by the crew to the harbor authority.

On the other hand, image intensifiers can not operate at long ranges because of the minimum light intensity necessary to obtain a reasonable contrast off targets. Using a CW laser illuminator to supplement the lack of lighting is a low cost solution but it performs very poorly in maritime environment because of the humidity content. Ranges in order of only few hundreds of meters can be expected in good visibility conditions.

4.2. Range-Gated Technology

Obzerv's active imaging systems (ATV-2000i) incorporate range-gating technology, also known as time-gating technology. Unlike other night vision technologies, range-gating does not require ambient light sources nor suitable moonlight to function effectively. Range-gating technology operates in the Near-infrared (NIR) and combines two key components: a pulsed laser diode source (the DALIS™ illuminator) and a specially designed camera intensifier that function both at high speed. The ATV-2000i also includes a high magnification continuous motorized zoom telescope (60 to 240 X magnification) and an intuitive graphical user interface (GUI).

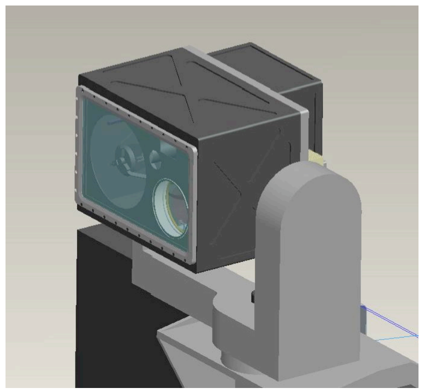

Figure 2: Illustration of the ATV-2000i mounted on a motorized pan & tilt platform

Using the ATV-2000i, Obzerv has demonstrated that range-gating systems can provide the required information to make a good and efficient situational assessment. This is illustrated by the two following examples. At the Figure 3, the ATV-2000i was looking at a small boat detected by a micro-bolometer thermal imager at 1.9 km away. The pictures on the right shows the details that can be seen using a range-gating system. The operator could see inside the wheelhouse, confirm the name of the fishing boat, and count the number of individuals on the deck.

Figure 3: A fishing boat at 1,9 km seen by a thermal imager (a) and the ATV-2000i (b and c)

As seen at the Figure 4, the surveillance system was oriented toward a large ship cruising off the coast at 6,4 km. From the video sequence, it is easy for the operator to read the ship's name with a probability of 100%. The activity on the deck can also be assessed without any problem. Moreover, looking at the zoom out picture in the center, the operator could measure the floating line level and confirm the load of the ship according to the declaration of the crew. All these information could not be available with the other technologies that were mainly developed with the detection mission in mind.

Figure 4: A large ship at 6,4 km as seen by a thermal imager (a) and by the ATV-2000i (b and c)

4. CONTROL OF THE LASER ILLUMINATION

4.1. The illumination source.

Range-gated active imagers, although providing more detailed information, are based on an illumination source that must be powerful to achieve long range performance at video rate. A laser is the best appropriate source of illumination because of its low divergence and its mono-chromaticity. The low divergence allows to maintain the power density high in the field of view of the camera. The mono-chromaticity facilitates the selection of the pass band filter in front of the sensor to reject most of the parasitic illumination. However, the laser sources required in all efficient active range-gated imaging systems, whatever their wavelength, can be dangerous at close range and like for any other radiant sources (radar, designator, LIDAR etc.) , it must be controlled properly to assure a completely safe installation on all aspects.

4.2. Characteristics of the DALIS™ laser source

Obzerv mandated in 2004 an independent laboratory, the DRDC (Defense R&D Canada) Valcartier to produce a laser safety analysis of the laser based ATV-2000i active imagery camera. The ATV-2000i uses a laser source based upon an array of laser diodes which together produced an homogeneous laser beam. In fact, one hundred and fifty (150) laser diodes are collimated with a special patented micro collimation process. The beam is composed of independent sources that are multimode. This means that there is no possibility of phase recombination of the beams and then no bright spot in the beam that could make it more dangerous for the eye. Using a multimode laser source, besides its better uniformity, provide a speckle free operation.

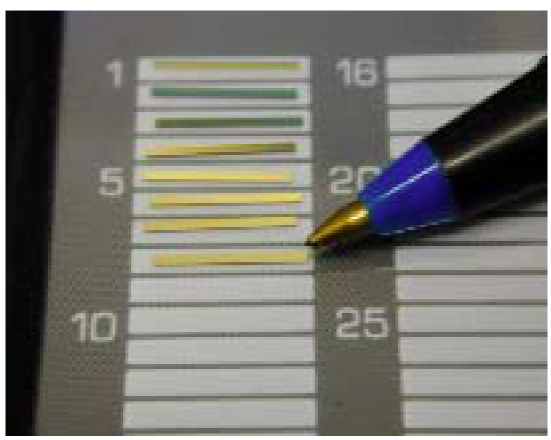

Figure 5: Picture of laser diode bars

4.3. Nominal Ocular Hazard Distance (NOHD)

To understand the laser safety analysis, there are three important definitions to retain: the MPE is the maximum permissible exposure. It is the level of radiation to which a person may be exposed without any hazardous effect to the eye. These values are established according to the standard established by the certification agencies (Ref 1.) with a security margin.

The NOHD is the distance along the laser beam to the point at which the beam does not exceed the laser's maximum permissible exposure (MPE).

Finally, because the output wavelength of the laser is in the NIR, the calculations must be performed for an exposure duration of 10 seconds for someone looking directly into the beam.

The basic equation for NOHD calculations (neglecting the atmospheric attenuation) is:

$$NOHD = \frac{1}{\phi}\sqrt{\left(\frac{4\Phi}{\pi MPE}\right) - a^2}$$

The current version of the ATV-2000i is described in the following Table 1.

Wavelength	861 nm
Pulse Repetition Rate	Variable; 15.75 kHz typical, up to 30 kHz
Average Output Power	17.1 Watts (70% within nominal divergence)
Pulse Width	200 ns up to 6 µs
Beam Profile	Rectangular
Beam Distribution	Approximately super-gaussian or flat top profile
Minimum Vertical Divergence (mrad)	4.8 (1/e)
Maximum Vertical Divergence (mrad)	16.8 (1/e)
Output Beam Maximum Dimensions (@minimum divergence)	5.7 (horizontal) x 8.5 (vertical) cm
Output Beam Minimum Dimensions (@maximum divergence)	1.7 (horizontal) x 2.3 (vertical) cm

Table 1: Characteristics of the ATV-2000i

The naked-eye (NOHD) and Extended NOHD (ENOHD), for observation using 7X 50mm binocular, were calculated for the worst case scenario of the emission of the system. These calculations were also repeated should Obzerv manufacture an ATV 2000i that would operate at 1550 nm in a future version. The results are shown in the table 2-2.

Wavelength (nm)	NOHD (m)	ENOHD (m)
861	435	2610
1550	26	164

Table 2: Results of the calculations of the NOHD and ENOHD

According to the Standard ANSI Z136.1 (2000), any laser operating above 0.5 W of optical power is a Class-4 laser source. Worst-case scenario (maximum output, minimum laser divergence) calculated NOHD and ENOHD at the current wavelength of operation of 861 nm, are 435 m and 2610 m respectively. Operating at 1550 nm, although that it would reduce the distance significantly (NOHD of 26 and ENOHD of 164 m), will still need particular precautions at the installation stage.

As mentioned earlier, the laser used in the ATV-2000i is not a classical laser just like the YAG laser, the laser diode source has a variable power control. The ATV-2000i modulates the laser power and the laser pulse width according to the real-time scenario. By doing so, it is possible to manage the NOHD more efficiently using operator procedures and mechanical masking.

4.4. ATV-2000i design for a safe operation

In designing the ATV-2000i, Obzerv has taken the former calculations seriously into account. To use as less laser power as possible, a significant effort was made to maximize the transmission of the optical channel of the ICCD by increasing its aperture size. In doing so, we have reduced the laser power that was necessary to produce a good quality image for the operator. In its current version, if the operator does not saturate the image, the laser power required will always be such that, at a given ranges, the NOHD will be much less than the observation range. As an example, when the operator looks at a target located at a distance of about one km in clear atmospheric condition, the power normally used will be less than 0.5 watt at low divergence and the NOHD will then be less than 85 m (ENOHD less than 510 m).
Moreover, as stated in the Ref 1. (para 4.2.6), it is important to note that all objects illuminated by the laser are seen by the operator. The laser beam is always limited within the FOV of the camera. This assures that the operator is always monitoring in all times the presence of objects that could be located in the non eye-safety zone and can act very quickly to make sure that no one is submitted to the 10-second exposure duration at any time.

4.5. Current NOHD Computation

Notwithstanding the above, Obzerv has developed an innovative tool to support the operator in the area of laser safety: the real-time display of the current NOHD. The current NOHD is computed inside the ATV-2000i using the current field of illumination (FOI) and the Laser Output Power. The laser power is measured many times per second by an Optical Pickup Sensor. The computed value is available both on the video overlay and on the console display. This feature gives the operator an instantaneous feedback on the laser output power level. In turn, this value is used to compute the following equation providing the current NOHD:

Parameters	Description
$NOHD$	Current value of the NOHD (m)
$NOHD_{MAX}$	Maximum value of the NOHD (m)
FOI	Current value of the FOI (mrad)
FOI_{MIN}	Minimum value of the FOI (mrad)
L	Current value of the laser power (mW)
L_{MAX}	Maximum value of the laser power (mW)

Table 3: Parameters selected to compute real-time NOHD value.

$$NOHD = NOHD_{MAX} \times \frac{FOI_{MIN}}{FOI} \times \sqrt{\frac{L}{L_{MAX}}}$$

The Human Machine Interface (HMI) software is used to control all user functions of the ATV-2000i. The HMI is based on a PC computer that exchange the data with the camera over a TCP/IP network. It sends all the commands but it is also used to inform the operator of the laser operation in three ways:

4.5.1. Status

The Figure 6 shows how the information is displayed in real-time to the operator. Six LED indicators provide the current BIT state of the ATV-2000i. Green LED means that the parameter is OK. Red LED means that there is a problem. The interlock circuitry is special and is indicated by an amber LED when it is active.
The variable laser power output is displayed on top with the current and maximum NOHD just below.

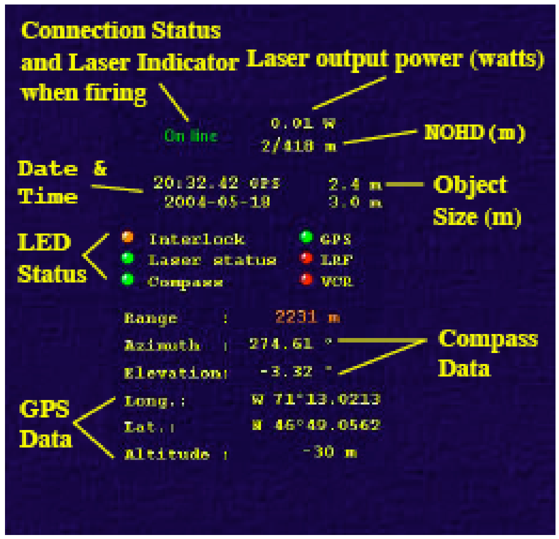

Figure 6: Status area in the Human Machine Interface

4.5.2. Range Slider

In active mode, a range-gate slider is displayed at the bottom of the video screen. It is used to control the range and the width of the gate of the system. The left cursor is used to select the range of the gate while the right one is used to select the width of the gate. As illustrated at the Figure 7, the NOHD is represented graphically at the left of the slider. The maximum NOHD is displayed as an empty orange rectangle. The current NOHD is represented with a solid red rectangle.

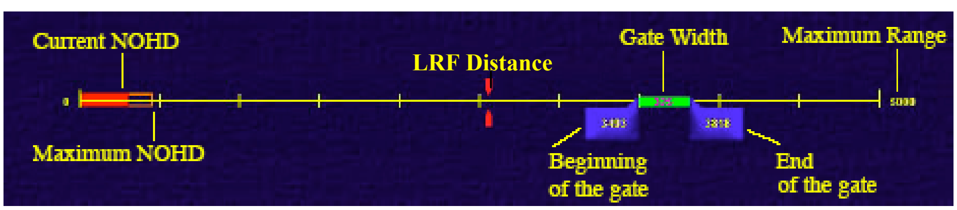

Figure 7: Range-gate cursor and indicator

4.5.3. Video overlay

At the output of the camera, the video signal includes a video overlay that displays all the necessary data needed to be recorded to track an potential incident. The data that is overlaid on the video is shown at Figure 8. Besides the time and date on top of the image, the laser power, the maximum NOHD, the current NOHD and the range of the target are indicated. There is also an indication if the interlock circuit is active or disabled.

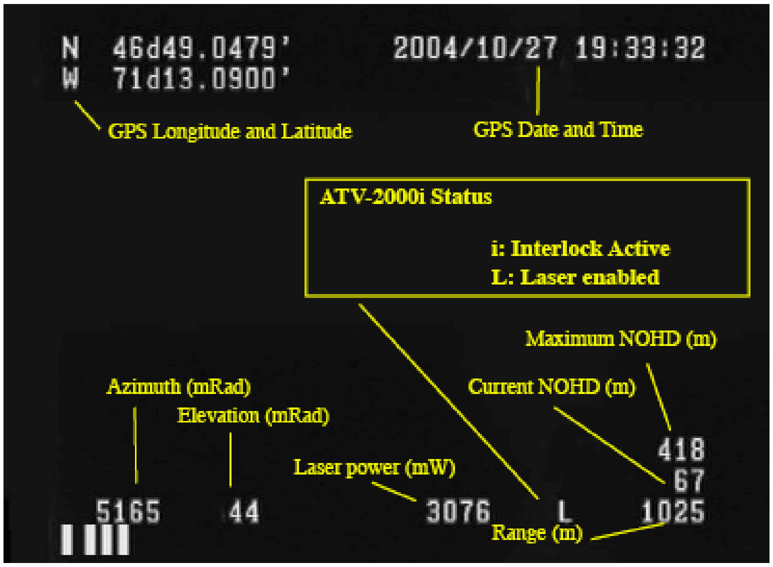

Figure 8: Video overlay

4.6. Precautions during installation

For long range surveillance, the sensors are always installed on a top of a building or a tower to cover the maximum distance. As it is the case with radar station, in such a situation, a limitation (masking) can be imposed on the control software embedded in the camera to monitor at all times the position of the Pan & Tilt platform. The camera will then adapt the NOHD (ENOHD) of the system by adjusting the maximum laser power available to the operator according to a pre calculated nominal zone (NHZ). This NHZ will be established following a local survey before installation (ref 1, section 4.5.3). For example, as illustrated in the Figure 9, when looking below the horizon, the maximum laser power could be reduced to 100 mW for angle lower than -5 degrees, 0.5 W between -5 and -2 degrees and completely restored when the elevation angle of the platform is above -2 degrees.

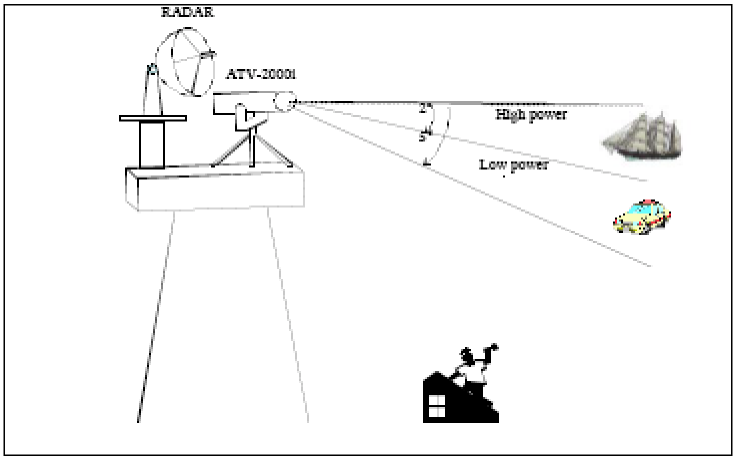

Figure 9: NOHD control according to pan & tilt angles.

5. CONCLUSION

When considering a complete and efficient surveillance system, security agencies are taking into account the threat level and the type of protection they must offer to the high-value assets. Traditionally, for harbor and coastal surveillance, radar stations have been the long range detection tools. To provide a better identification of contact targets and classify probable threats, they have been using color CCD, image intensifier, thermal imager, etc. Unfortunately, none of those technology can fulfill the mission of long range identification at distance that can provide them with enough time to react.

The ATV-2000i is a NIR range-gated active imager with a magnification up to 240X that can allow an operator to read a ship's name at more than 7 km and determine a threat level at 5 km, long before it becomes a real menace. Unfortunately, the range-gated technology uses a laser source that has an eye safe distance to be respected when operating at these very long ranges.

Obzerv has recognized these facts for a long time and while developing a very efficient surveillance instrument, it also develops the required tools to help out the operator to work in a completely safe manner once the system is installed properly.

These tools are based on a variable laser power output and on a real-time NOHD calculator. Working together under the control of the embedded computer, the ATV-2000i offer a safe solution for a tougher surveillance mission.

REFERENCES

1. ANSI Z136.6-2000, American Standard for Safe Use of Lasers Outdoors