New robust and highly customizable light source management system

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ABSTRACT

In semiconductor lithography, light sources play a significant role in the wafer production process as well as impacting the manufacturing cost per wafer. Chip manufacturers going forward will be challenged to develop new ways to become more cost effective than their competitors, and the software tools necessary to compete in this environment must be capable of effectively adapting to the unique needs of each manufacturer. Gigaphoton has developed a new highly customizable software system for managing light sources. It not only offers a simple and intuitive user interface that can be operated using a standard web browser on PCs, tablets, and smartphones, but also a platform for users and third parties to develop unique extensions and optimizations.

Keywords: light source management, web, monitoring, lithography

1. INTRODUCTION

Fueled by the “mobile” consumers, with their smartphones, tablets and now IoT, the demand for smaller, cheaper, faster, and more energy efficient chips continue to grow stronger every year.The competitive environment for chipmakers is also growing fiercer.Differentiation can no longer be achieved through design technology alone.Cost has now become just as important a differentiator — if not more important — for chipmakers.However, addressing the ever growing demand on cost reduction is a great challenge and manufacturers will not be able to take anything for granted.In semiconductor lithography, light sources play a significant role in the wafer production process as well as impacting the manufacturing cost per wafer.Maximizing the efficiency, uptime, and maintenance cost of every lights source will become increasingly important for chip manufacturers, and as these requirements become more strict and unique across users and even individual fabs, generalized solutions may no longer be able to accommodate every need.

Most chip manufacturing sites or “fabs” today consist of multiple light sources from different vendors, and chipmakers rely on each vendor’s proprietary software solutions to monitor and manage their systems.These vendor’s software solutions, which are typically developed in a closed environment, are primarily designed to operate only with their own products.While this may offer highly optimized and effective solutions for their respective light sources, it can also pose a burden on chipmakers, requiring them to learn and use different software solutions depending on the light source vendor to effectively manage a single fleet of tools in their fab.Chipmakers may enjoy new features and improvements from one vendor solution but its benefits can only be applicable to the subset of light sources offered from that vendor.

Furthermore, due to the lack of industry standardization and open innovation processes, the technical roadmaps, including the level of effectiveness and usability of each software solution, vary and are often driven by economics and the investment strategy of each vendor.This can also pose a burden on chipmakers as no single solutions can be relied upon to be useful and effective fab-wide for all light sources regardless of vendor.

In the lithography space, the light source plays a significant role in the wafer production process as well as the manufacturing cost per wafer.Software tools that offer the ability to effectively monitor the performance and health of light sources have been invaluable for anticipating and planning maintenance and downtimes, as well as keeping track of various laser parameters that affect the wafer outcome.However, chip manufacturers going forward will be challenged to develop new and innovating ways to become more competitive, and the software tools necessary to compete in this environment must be capable of effectively adapting to the unique needs of each manufacturer.

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For example, some of the most important items to accurately monitor on a light source is wavelength and bandwidth stability.Instability in these parameters leads to focus and magnification errors which in turn lead to image contrast degradation, and critical dimension (CD) and overlay errors.Similarly, monitoring the laser power stability is also important as it affects the dose uniformity or the consistency of the total amount of light that is exposed on the wafer materials.These are just some of the key items that affect the overall laser performance and ultimately the wafer yield.There is much more data available for in-depth monitoring and analysis but different users have different needs. Hence it is desirable for tools to be capable of being optimized to the specific needs of each user to meaningfully monitor items of interest and maintain an optimal production environment. Gigaphoton's new light source monitoring solution concept not only offers the industry a robust and highly customizable solutions that facilitates the unique needs of chip manufacturers, but also with the opportunity and potential to drive a more unified solution through open innovation and collaboration processes.

2. GENERAL SYSTEM OVERVIEW

2.1 Concept

REDeeM Cloud™ is a new monitoring solution developed by Gigaphoton for managing light source performance and operations.It is a compact and portable web-based solution that can be installed on a local server running in a closed network environment or on a secure external server infrastructure.The monitoring tool can be operated using a standard web browser on any PC, or on most of today's popular mobile devices such a tablets and smartphones.REDeeM Cloud™ embraces open technology concepts and is itself targeted to be an open source project.This enables the solution to adapt to the evolving needs of each chip manufacturer.As an open source project, the chip manufacturers themselves will be free to optimize, expand or distill the solution as they see fit to accommodate their specific needs, and third parties, including light source vendors, may also continue to develop and offer new improvements, features and extensions to the system – possibly in conjunction with additional metrology hardware options.The architecture enables the solution to harness the full power of open source communities to constantly evolve, and improve itself without being bound to the technical capabilities, resources and the strategic roadmap of a single company.All development activities will be centered on a single open solution platform, and its benefits are not necessarily limited to a specific vendor's products.The goal is to ultimately enable users to consolidate all of their monitoring tools into a single solution, thus maximizing the efficiency and effectiveness in managing their entire fleet of light sources.

2.2 Architecture

The two primary components of REDeeM Cloud™ are the REDeeM Front End (RFE) Server which provides the system's User Interface (UI) and the REDeeM Back End (RBE) Server which collects, processes, and services the data (see Figure 1). A UI is the visual interface where all human interaction with the system takes place.The RFE services the UI through a type of software application that runs in a browser called a web application or "web app." Unlike previous software applications (excluding those that are Java based) that run only on the specific Operating System (OS) it is developed for, a web app does not rely on any particular OS.This allows more flexibility in terms of operating environments, and users are no longer bound to a particular OS or PC hardware.Many software products are developed such a way that it is highly dependent on not only the OS but also its version, and often times the companies that provide the software is unable to keep up with the evolution of the OS and forces the user to maintain an old version of an OS – sometimes beyond its support lifetime.With web apps, backwards compatibility is typically not an issue and it is usually sufficient that the latest standard web browser is available and installed.There may, however, be constraints on the some web browsers that do not fully confirm to industry accepted web technology standards.

The RBE is responsible for collecting, analyzing, storing, and supplying all parameter and status data form the light source necessary for maintaining optimal performance and efficiency.The light source hardware constantly monitors and record data point that affect not only its own performance but ultimately the quality of the wafers it is used to fabricate.The raw performance data is either automatically collected directly from the light source or manually uploaded via the RFE, and accumulated in a relational database where it is organized for quick data sorting, filtering and retrieval.The primary data handled by the RBE consists of periodic and real-time light source status information which are critical for monitoring the performance of the laser.The laser is a

Other forms of data include user accounts, group definitions, light source registration, data type definitions, and user preferences.

The retrieval of any monitoring data from the database is accomplished through a Web Application Programming Interface (Web API) which is integrated into the RBE.A Web API is a request-response data exchange method based on the Internet's standard Hypertext Transfer Protocol Secure (HTTPS).It offers a robust means for data access that is optimal for both programmatic and human-readable interactions.It also envelops the database with a layer of abstraction for effectively handling variations in data formats and also security, which prevents external sources from directly accessing the database.

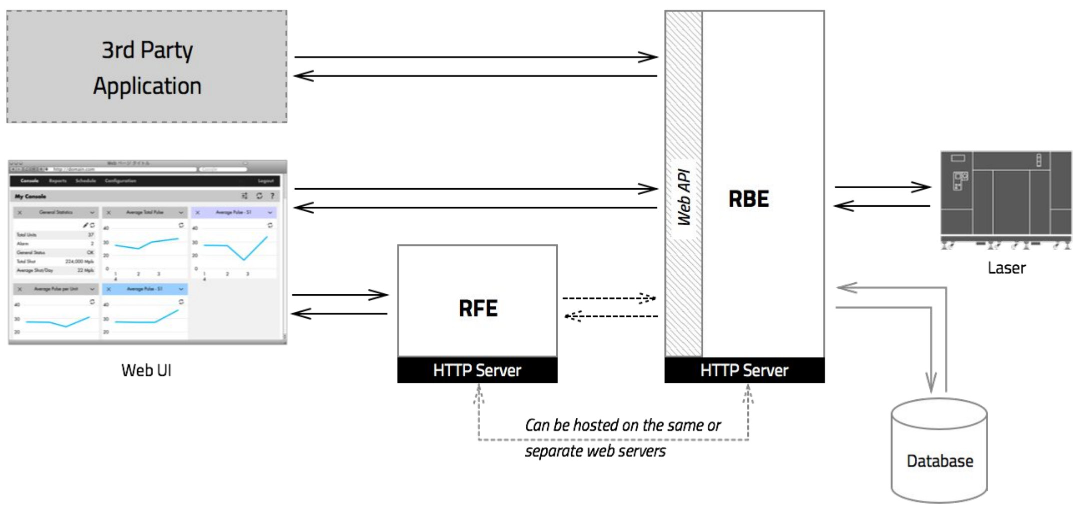

Figure 1. The basic architecture of REDeeM Cloud™.

These two key components are both web-based services.They are essentially small web sites that can run separately on its own standalone web server or together on a single web server separated by unique paths.Although both the RFE and the RBE can run independently from each other – even on separate physical servers – the RFE is dependent on the RBE for retrieving all the source data it requires to execute various features such as plotting graphs, registering light sources, managing users, analyzing errors, and more.

3. WEB APPLICATION

The RFE services a fully featured application for monitoring light source performance.It is designed as a standalone web application server that runs on a standard web server platform such as Apache[1].The software itself is developed using a combination of widely adopted web technologies including HTML[2], CSS[3], PHP[4] and JavaScript[5].The primary function of the RFE is to provide a means for users to interact with the REDeeM Cloud™ system and for visually displaying the light source monitoring data in a meaningful way.It is not meant to perform complex data analysis or manipulations, which are tasks primarily reserved for the RBE.The RFE code is compatible with a variety of open source libraries and frameworks that are built on top of the base scripting languages such as PHP and JavaScript.These help to create rich user interfaces with relative ease and minimize overall development lead time and effort.Responsive

Web Design[6] principle are also implemented so the user interface will automatically optimize its content, layout and size depending on the browser being used to view the content.

Users are free to use the web application as-is or as a template for developing their own customized user interface (UI).As an open source project, users and third parties will be free to develop and deploy any modifications or extensions as long as they adhere to the terms of its open source license.

3.1 Standard Features

Standard features include: a customizable dashboard, light source utilization statistics, parts health status, parts exchange forecasting, plot analysis, long-term trending, error analysis, maintenance scheduling, and more.Optional extensions are also available to view detailed wafer or burst level beam data in conjunction with Gigaphoton's Beam Performance Monitor (BPM) metrology module[7] (see Figure 2).

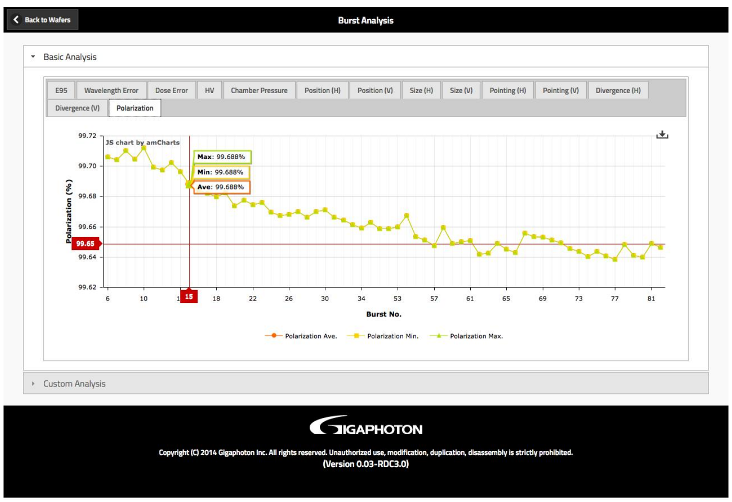

Figure 2. Sample screen plotting the burst level data.

The REDeeM Cloud™ system is also equipped with its own user account management feature for managing user access to light source data.Adding, deleting and modifying user accounts can be accomplished through the RFE.Once the logged into the system, the user is first taken to customizable dashboard called "My Console" (see Figure 3) where various panels can be pasted for quick view and/or access to data.Several types of panels are offered by default such as the running status of a light source and the status of a group of light sources.In addition, any saved plot data can be added to the dashboard for quick access to plots that are viewed often.

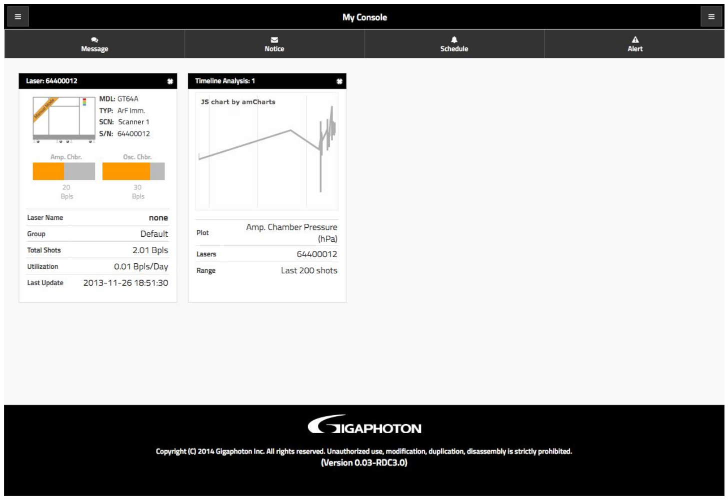

Figure 3. The user customizable My Console screen.

4. WEB API

The Web API serviced by the RBE provides a secure and controlled means for external applications to access information contained in the database and/or analysis data based on the collected data.The web application serviced by the RFE retrieves all of the data required for its monitoring functions using the Web API, but any external application can also leverage the same service.This is especially useful for users developing their own software for managing tools and want to integrate laser management into their system.The Web API is based for the most part on a Representational State Transfer (REST) API architecture, which is widely used by many web sites today that allow their services to be integrated into third party web sites and applications.

5. NETWORK CONFIGURATION

REDeeM Cloud™ offers the flexibility of running exclusively within a closed corporate network environment or in synchronization with a secure, externally accessible infrastructure – allowing users the convenience of remotely monitoring their tools from virtually anywhere using a PC or mobile device.

The most basic network configuration is the installation of a single server to manage a fleet of light sources in a closed network infrastructure (see Figure 1).The Client PCs used to operate the RFE must also be connected to the same closed network.In this scenario, there is no connection to the outside world (including fab networks in other sites) so no synchronization of data is possible.Hence, Client PCs must access this specific server to manage the light sources in Laser Group 1.

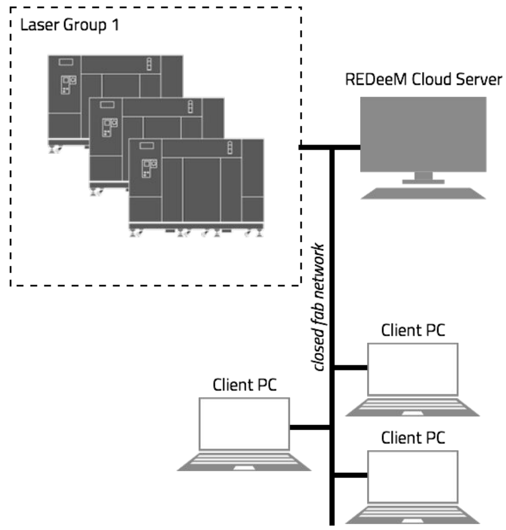

Figure 4. An example of the most basic installation scenario.

Managing a broader coverage of light sources is possible by installing more than one servers across different fabs or sites. REDeeM Cloud™ has the ability to synchronize its database across multiple servers (see Figure 5).This allows user privileges and access restrictions to be centrally managed, and also distributes server load for better performance.In this scenario, one server must be designated as the Primary server, which has the highest administrative privileges.All other servers are designated as subordinate servers or "Sub" servers and will bear some constraints depending on the configuration.

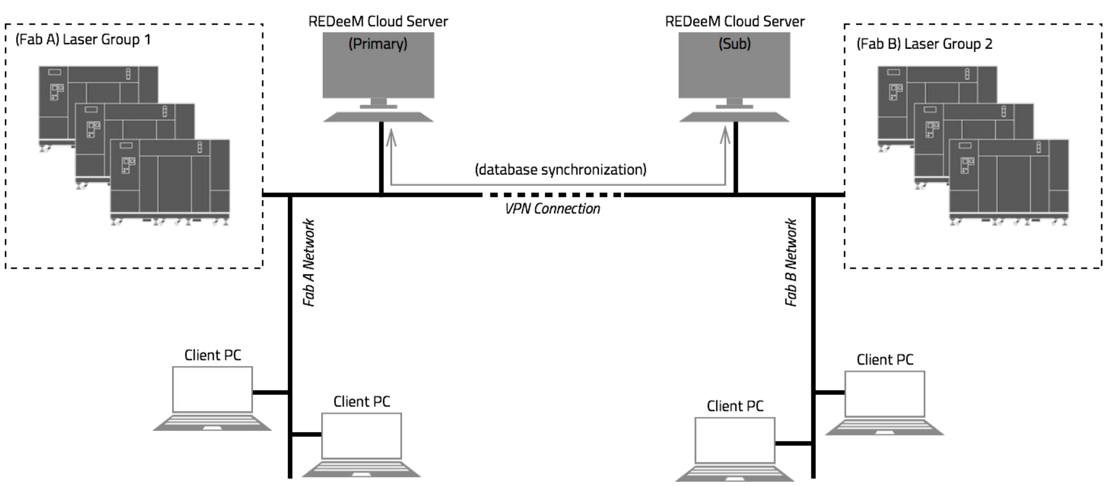

Figure 5. An example of a multi-system installation scenario

Another scenario involves the synchronization of data with an external server.The key benefit of integrating with an externally facing RFE server is the ability to remotely monitor light sources from anywhere there is an Internet connection including the use of mobile devices such as tablets and smartphones.In such a scenario, the data synchronization with the external RBE will be done through a secure tunneling protocol.The RFE will also be accessed using HTTP Secure (HTTPS) protocols.

A secure, externally accessible infrastructure can be realized in several ways.For example, the user can simply set up a REDeeM Cloud™ server that is accessible from the outside through a Virtual Private Network (VPN) connection.Alternatively, users can synchronization with Gigaphoton's secure server infrastructure, which relieves the user from having to maintain a separate server and at the same time helps to facilitate a higher level of maintenance and support services for the light sources (see Figure 6).

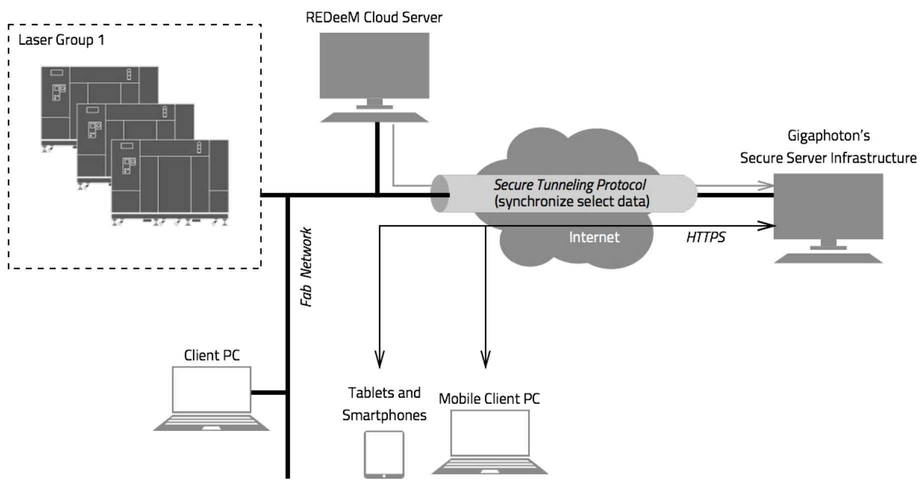

Figure 6. An example of configuring the system to synchronize with Gigaphoton's secure server infrastructure.

6. SUMMARY

Most chip manufacturing sites or "fabs" today consist of multiple light sources from different vendors, and chipmakers rely on each vendor's proprietary software solutions to monitor and manage their systems.These vendor's software solutions are primarily designed to operate only with their own products.

REDeeM Cloud™ is a new monitoring solution developed by Gigaphoton for managing light source performance and operations that embraces open technology concepts.Open technology offers chip manufacturers the freedom to customize the solution as they see fit, while third parties, including light source vendors, also continue to develop and offer new improvements, features and extensions to the system.The key benefit compared to previous systems is that all development activities will be centered on a single open solution platform, and its benefits are not necessarily limited to a specific vendor's products.

The two primary components of REDeeM Cloud™ are the REDeeM Front End Server which provides the system's User Interface and the REDeeM Back End Server which collects, processes, and services the data.It offers the flexibility of running exclusively within a closed corporate network environment or in synchronization with a secure, externally accessible infrastructure – allowing users the convenience of remotely monitoring their tools from virtually anywhere using a PC or mobile device.

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